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STS 41-B/

PALAPA B-2
WESTAR VI

Launch Vehicle—Space Shuttle Challenger, built by Rockwell International, Downey, CA.

Program Overview—Space Shuttle is a true aerospace vehicle. It takes off like a rocket, maneuvers in Earth orbit like a spacecraft, and lands like an airplane. It is designed to carry heavy loads into Earth orbit. The Space Shuttle can be used again and again.

Moreover, Shuttle permits checkout and repair of unmanned satellites in orbit or return of the satellites to Earth for repairs that could not be done in space.

Interplanetary spacecraft also can be placed in orbit by the Shuttle, together with a rocket stage called the Inertial Upper Stage (IUS). Following deployment from the Shuttle, the IUS is ignited to accelerate the spacecraft into deep space.

The Shuttle flight system is composed of the orbiter, an external tank (ET) and two solid rocket boosters (SRBs). Each booster rocket has a sea-level thrust of 2.6 million pounds (11.6 million newtons). The orbiter and SRBs are reusable, and the external tank is expended with each launch.

The orbiter is 122 feet (37 meters) long and 57 feet (17 meters) high, with a wingspan of 78 feet (24 meters) and a weight, without fuel or payload, of 150,000 pounds (68,000 kilograms). It is about the size and weight of a DC-9 commercial air transport.

The orbiter can transport a payload of 65,000 pounds (29,500 kilograms) into orbit. It carries its cargo in a payload bay 60 feet (18.3 meters) long and 15 feet (4.6 meters) in diameter.

The orbiter's three main liquid-fueled engines each has a thrust of 470,000 pounds (2.1 million newtons). They are fed propellants from the external tank which is 154 feet (47 meters) long and 28.6 feet (8.7 meters) in diameter.

At liftoff, the external tank holds 1,550,000 pounds (703,000 kilograms) of propellants, consisting of liquid hydrogen (fuel) and liquid oxygen (oxidizer). The hydrogen and oxygen are in separate pressurized compartments of the external tank.

The crew occupies a two-level cabin at the forward end of the orbiter. The crew controls the launch, orbital maneuvering, atmospheric reentry and landing phases of the mission from the upper-level flight deck. Payload handling is accomplished by crew members at the aft cabin payload station. A living area is provided on the lower deck.

Crew members experience a designed maximum gravity load of only three Gs during launch and less than 1.5 Gs during a typical reentry.

Landing speed for the orbiter is 210 miles (335 kilometers) an hour. A Shuttle crew can be as many as seven people.

NASA's Lyndon B. Johnson Space Center in Houston, TX, manages the Space Shuttle program and is responsible for development, production and delivery of the orbiter. The astronaut office is located at this NASA center.

NASA's Goddard Space Flight Center in Greenbelt, MD, is responsible for space communications.

NASA's George C. Marshall Space Flight Center in Huntsville, AL, is responsible for the development, production, and delivery of the solid rocket boosters, the external tank and the orbiter main engines. Test firings of the Shuttle engines are carried out at NASA's John C. Stennis Space Center in Bay St. Louis, MS.

NASA's John F. Kennedy Space Center, FL, is responsible for design and development of launch and recovery facilities and for operational missions requiring easterly launches.

Project Objectives—The primary goal of the eight-day Challenger mission—the tenth for the Space Shuttle—was the deployment into orbit of two commercial communications satellites, Western Union's Westar VI and the Indonesian Palapa B-2.

The remainder of the flight was devoted to a series of rendezvous maneuvers—including two spacewalks—using an inflatable balloon as the target; test flights of two Manned Maneuvering Units (MMUs); and checkout of other equipment and procedures to be used by the Challenger crew in its April 1984 flight (STS 41-C), for the historic attempt at the on-orbit retrieval and repair of the Solar Maximum Mission (SMM) satellite.

The spacewalks—or extravehicular activity (EVA)—were conducted on flight days five and seven. The Flight Day Five EVA was 5.5 hours in duration; on Flight Day Seven, six hours.

The crew of Challenger (OV-099) was: Vance D. Brand, Mission Commander, who also commanded STS-5, the first fully operational flight of the Space Shuttle; Lt.Cmdr. Robert L. ("Hoot") Gibson, USN, Pilot, on his first space mission; and Mission Specialists Maj. Robert L. Stewart, USA, Dr. Ronald E. McNair and Cmdr. Bruce McCandless II, USN. McCandless and Stewart made the EVAs.

Spacecraft Description/Payload—Westar VI was the third advanced Western Union communications satellite in orbit and the first Westar satellite to be launched from the Space Shuttle. Built by Hughes Aircraft Company, El Segundo, CA, the spacecraft was intended as part of a five-satellite system, providing continuous video, facsimile data and voice communications service throughout the continental U.S., Alaska, Hawaii, Puerto Rico and the Virgin Islands.

This spacecraft had 24 transponders and six backup transponders. Each transponder was capable of handling 2,400 one-way voice circuits or a color TV transmission. This particular Westar was to have been dedicated to business communications.

Palapa B-2 was deployed to provide 24 additional transponders to the communications network that serves the island nation of Indonesia and the Association of Southeast Asia Nations (ASEAN), consisting of the Philippines, Thailand, Malaysia, Singapore and Papua, New Guinea.

The Palapa was built by Hughes Communications International, Inc., Los Angeles, CA.

Other Payloads—A variety of payloads/experiments was carried on board Challenger:

- Shuttle Pallet Satellite (SPAS-O1A). Although not deployed on this mission, this West German-built platform duplicated the attitude/dynamics of the SMM during the astronauts' rehearsal for the April 1984 SMM repair mission.

- Cinema 360 Camera. Two of these were on 41-B, one in the crew module and another in the payload bay. They obtained photography as part of a test for the use of 35mm motion picture photography in a unique format, designed especially for planetarium viewing.

- Integrated Rendezvous Target (IRT). The IRT was a spherical surface with special radar and visual characteristics. A target for on-orbit testing of Shuttle orbiter rendezvous techniques and capabilities, the IRT was deployed four hours early on Flight Day Three but failed to inflate. However, Rendezvous Radar (RR) work was successfully done using the deflated IRT balloon.

- Monodisperse Latex Reactor (MLR). This experiment manufactured tiny identically-sized latex beads which may have major medical and industrial research applications.

- Acoustic Containerless Experiment System (ACES). This was a materials processing furnace, enclosed in two airtight canisters in the orbiter mid-deck. It provided data to the experimenters in conjunction with its preprogrammed sequence of operations on a material sample.

- Isoelectric Focusing Experiment (IEF). Another of the self-contained experiment packages. The IEF evaluated the effect of electro-osmosis on electrolyte solutions.

- Shuttle Student Involvement Project (SSIP). This experiment tested the effects of weightlessness on the development of arthritis, using six rats as the test subjects, and provided data to the experimenters.

- Radiation Monitoring Equipment (RME). The RME provided data on its active measurement in the crew cabin of gamma radiation exposure to the crew.

- Get Away Special (GAS). Six GAS canisters flew in Challenger's cargo bay: five with experiments, the sixth with the Cinema 360 camera equipment. Managed by NASA/Goddard Space Flight Center, Greenbelt, MD, the GAS program permits individuals, corporations, government agencies, and institutions an opportunity to fly scientific payloads aboard the Shuttle for a fee.

Project Results—STS 41-B was launched from Kennedy Space Center, FL at 8:00 a.m. (EST) on February 3, 1984.

The mission timeline for the first four days had to be changed after deployment of Westar VI on Flight Day One and its subsequent failure to achieve the proper orbit. The Palapa B-2 deployment was delayed from Flight Day Two to Flight Day Four, following a decision by the Indonesians and Hughes and McDonnell Douglas Aircraft Corporations. Although successfully deployed, both satellites failed to achieve geosynchronous orbit due to onboard Propulsion Assist Module (PAM) failure.

However, there were no major anomalies on this flight that would affect future mission planning.

Challenger touched down on Kennedy Space Center runway 15 at 7:16 a.m. (EST) on February 11, 1984.

This Challenger mission accomplished three major firsts:

- First flight of the Manned Maneuvering Unit (MMU), a propulsive backpack worn by astronauts during EVAs.

- Excellent results of the Rendezvous Radar (RR) in tracking the deflated Integrated Rendezvous Target (IRT).

- Landing at Kennedy Space Center.

In summary, this historic flight considerably advanced Shuttle technology and paved the way for day and night operations out of Kennedy Space Center.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	J.A. Abrahamson
Associate Administrator for Space Science and Applications (OSSA)	B.I. Edelson
Director, Microgravity Science and Applications Division, OSSA	R.E. Halpern
Director, Shuttle Payloads Engineering Division	M.J. Sander

Goddard Space Flight Center, Greenbelt, MD

Director	N.W. Hinners
Director of Networks	R.S. Sade

Jet Propulsion Laboratory, Pasadena, CA

Project Scientist, Acoustic Containerless Experiment System (ACES)	M.B. Barmatz
ACES Instrument Development Manager	D.J. Kerrisk
Co-Investigator, ACES	D.D.Elleman

Johnson Space Center, Houston, TX

ACES Mission Manager	E.L. Michel

Marshall Space Flight Center, Huntsville, AL

Project Manager	V.H. Yost
Mission Manager	R. Valentine
Co-Investigator/Project Scientist, Isoelectric Focusing Experiment	R.S. Snyder, Rensselaer Polytechnic Institute, Troy, N.Y.
Principal Investigator (Chairman of the ACES Science Working Group)	R.H. Doremus, Clarkson College of Technology, Potsdam, N.Y.
Co-Investigator	R. Subramanian, University of Arizona, Tempe, Arizona
Principal Investigator, Isoelectric Focusing Experiment	M. Bier

Contractors

Rockwell International, Inc. Downey, CA	Orbiter
Martin Marietta Corp. Denver, CO	MMU
McDonnell Douglas Astronautics Co. Huntington Beach, CA	PAM
Hughes Communications International, Inc. Los Angeles, CA	Palapa B-2 satellite
Hughes Aircraft Co. El Segundo, CA	Westar VI satellite

Launch Vehicle—Delta 174, a 3920 version of the expendable launch vehicle, was used to launch Landsat-D Prime (Landsat-5 when in orbit) into a circular, near-polar, Sun-synchronous orbit.

The Delta 3920 was 116 feet (35.5 meters) long including the spacecraft shroud. Liftoff weight was 4283 pounds (1947 kilograms). The first-stage booster was an extended long-tank Thor powered by the Rocketdyne RS-27 engine. This engine uses hydrazine (RP-1) fuel and liquid oxygen oxidizer. Start-up thrust was assisted by six of the nine Castor strap-on rocket motors (the remaining three motors were ignited at liftoff plus 60 seconds). Pitch and yaw steering was provided by gimballing the main engine. Vernier engines provided roll control during powered flight and coast.

The second stage consisted of large diameter propellant tanks with the Aerojet Improved Transfer Injector Program (ITIP) engine. This stage was powered by a liquid propellant engine using nitrogen tetroxide (N2 04) as an oxidizer and Aerozene 50 as fuel. Pitch and yaw steering during powered flight was provided by gimballing the engine. Roll steering during powered flight and coast was provided by a nitrogen gas thruster system.

Program Overview—The Landsat-D Prime program had these major objectives:

- To provide continuing Earth remote sensing information and to encourage continued national and international participation in land remote sensing programs;

- To assess the capabilities of the thematic mapper sensing system and to exploit new areas of the infrared and visible light spectra at higher resolution; and

- To establish a technical and operational proficiency which can be used to help define the characteristics necessary for potential future operational land remote sensing systems.

Following an orbital and ground system checkout and transition period, the data from the multispectral scanner as well as the operation of the Landsat-D Prime were turned over to the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) for operational management.

Project Objectives—Landsat-D Prime was identical to Landsat-D (Landsat-4 in orbit) and was to replace the Landsat-4 spacecraft when it was no longer operational. Landsat-4's lifetime estimates indicated a mid-1985 replacement date. Landsat-4 was launched July 16, 1982.

The launch of Landsat-D Prime was accelerated because of anomalies to Landsat-4's power generating system and one of its transmitting frequencies. Design changes were made to Landsat-D Prime to correct problems discovered on Landsat-4.

Carried piggyback on this mission was the UOSAT research spacecraft. Sponsored by the University of Surrey, England, the satellite was to provide a scientific and experimental spacecraft for the study of radio wave propagation and related space sciences by radio amateurs, amateur and professional scientists and educational establishments.

Spacecraft Description—Landsat-D Prime (Landsat-5 when in orbit) was built by the General Electric Co., Space Systems Division, Valley Forge, PA. It was about 14 feet (four meters) long and seven feet (two meters) wide and weighed 4348 pounds (1947 kilograms). The main body of the spacecraft consisted of NASA's standard Multimission Modular Spacecraft (MMS) and the Landsat instrument module.

The mast mount for the Tracking and Data Relay Satellite (TDRS) communications assembly extended about 13 feet (four meters) above the spacecraft body to provide a clear field-of-view to the relay satellite from horizon to horizon. An L-band antenna mounted on this mast provided a link with the Global Positioning System satellites.

The solar array, with its single axis of rotation drive mechanism, moved at orbital track rate to follow the Sun. It incorporated a fixed bend in the mount to orient the solar collectors perpendicular to the Sun.

The UOSAT satellite, built by the University of Surrey's Department of Electronics and Electrical Engineering, weighed approximately 132 pounds (60 kilograms). It measured approximately 14 inches × 14 inches × 25.4 inches (35 centimeters × 35 centimeters x 64 centimeters).

Spacecraft Payload—Landsat-D Prime's principal instruments were the thematic mapper and the multispectral scanner. Each instrument used an oscillating mirror to scan the Earth's surface in the cross-track direction (perpendicular to the spacecraft's ground track).

The thematic mapper used a multi-stage passive radiator cooler for temperature control of the thermal band detectors. The cooler is on the side of the spacecraft opposite the Sun.

Data from Landsat-5 either were relayed by the TDRS to the White Sands, New Mexico, Ground Terminal and relayed to the Goddard Space Flight Center, Greenbelt, MD., or they were transmitted directly by the spacecraft to Goddard. At Goddard, where the Landsat ground system consisted of a series of separated component systems, the data was processed and subsequently sent to the Landsat data distribution center at the Earth Resources Observation System Data Center in Sioux Falls, SD.

Project Results—Landsat-D Prime was launched successfully from Space Launch Complex 2 West, Western Space and Missile Center, Vandenberg Air Force Base, CA on March 1, 1984 at 9:59 a.m. PST.

The UOSAT spacecraft was separated from Landsat-D Prime and delivered to a near-polar orbit. The orbital elements were 429 statute miles (692 kilometers) apogee and 417 statute miles (674 kilometers) perigee with an inclination of 98.2 degrees.

Landsat-D Prime was then delivered by the Delta 174 to a higher, near-polar orbit of 434 statute miles (701 kilometers) apogee and 433 statute miles (699 kilometers) perigee with an inclination of 98.1 degrees.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Science and Applications	Dr. Burton I. Edelson
Associate Administrator for Space Transportation Operations	Dr. Stanley I. Weiss
Associate Administrator for Space Tracking and Data Systems	Robert E. Smylie
Director, Earth and Planetary Exploration Division	Jesse W. Moore
Deputy Director, Science, Earth and Planetary Exploration Division	Dr. Geoffrey Briggs
Deputy Director, Technical, Earth and Planetary Exploration Division	James C. Welch
Program Manager, Landsat-D	Harry Mannheimer
Director, Expendable Launch Vehicles Division	Joseph B. Mahon
Program Manager, Delta	Peter Eaton

Goddard Space Flight Center, Greenbelt, MD

Director	Dr. Noel W. Hinners
Director, Flight Projects Directorate	William C. Keathley
Project Manager, Landsat-D	Jon R. Busse
Deputy Project Manager, Landsat-D	Luis Gonzales
Deputy Project Manager, Resources	Frank L. Heddinger
Project Scientist, Landsat-D	Dr. Vince Salomonson
Flight Assurance Manager, Landsat-D	Albert Lunchick
Systems Manager, Landsat-D	Joseph B. Schulman
Systems Manager, Landsat-D Instruments	Joseph Arlauskas
Software Manager, Landsat-D	Lottie E. Brown
Ground Data Processing Systems Manager, Landsat-D	Jerold Hahn
Mission Operations Manager, Landsat-D	William C. Webb
Spacecraft Manager, Landsat-D	Richard A. Devlin
Instrument Systems Manager, Landsat-D	Oscar Weinstein

Delta Project Manager	David W. Grimes
Deputy Delta Project Manager, Technical	William A. Russell, Jr.
Manager, Delta Mission Analysis and Integration	J. Donald Kraft
Landsat Mission Integration Manager	Warner H. Hord, Jr.
Mission Operations and Network Support Manager	Robert I. Seiders
Mission Support	Ray Mazur

Kennedy Space Center, FL

Director	Richard G. Smith
Director, Cargo Operations	Thomas S. Walton
Director, Expendable Vehicle Operations Directorate	Charles D. Gay
Chief, Delta Operations Division	Wayne L. McCall
Chief, Delta Western Operations Branch	Ray Kimlinger
Manager, STS Resident Office (VAFB)	Pat Murphy
Spacecraft Coordinator	C.R. Fuentes

National Oceanic and Atmospheric Administration (NOAA)

Administrator	Dr. John V. Byrne
Deputy Administrator	Dr. Anthony J. Calio
Associate Administrator	James W. Winchester

NOAA National Earth Satellite Service

Assistant Administrator for Satellites	Dr. John H. McElroy
Acting Deputy Assistant Administrator for Satellites	Harold Yates
Director, Office of Systems Development	E. Larry Heacock
Director, Office of Data Services	Russell Koffler
Chief, Landsat Operations Division, Office of Data Service	Edward F. Conlan

Contractors

General Electric Company Space Systems Division Valley Forge, PA	Landsat-D Spacecraft Landsat-D Ground System
Hughes Aircraft Company Los Angeles, CA	Thematic Mapper Multispectral Scanner
Fairchild Industries Fairchild Space & Electronics Germantown, MD	Multimission Modular Spacecraft

STS 41-C/

LDEF-1
SSM REPAIR

Launch Vehicle—Space Shuttle Challenger built by Rockwell International, Downey, CA.

Project Objectives—The primary goal of the five-man Challenger crew was the on-orbit retrieval and repair of the malfunctioning Solar Maximum Mission (SMM)—Solar Max—satellite, the first such retrieval and repair ever attempted.

This was the eleventh flight of the Space Shuttle—and the first to employ a "direct insertion" ascent technique, putting the Challenger into an elliptical orbit with a high point (apogee) of about 287 miles (462 kilometers) and an inclination to the equator of 28.5 degrees.

A secondary objective of STS 41-C was the deployment of a large experiment carrier, the Long Duration Exposure Facility (LDEF). This large cylindrical payload, especially suited for carrying dozens of diverse, passive experiments, was left in space until it could be retrieved.

The Challenger crew for this mission was: Capt. Robert L. Crippen, USN, Mission Commander, the Pilot on the first flight of the Space Shuttle (STS-1), April 12-14, 1981 and the Mission Commander of STS-7, June 18-24, 1983; Capt. Francis R. (Dick) Scobee, USAF (Ret.), Pilot; and Mission Specialists Dr. George D. Nelson, Terry J. Hart and Dr. James D. van Hoften.

Solar Max—the Spacecraft and Its Mission

Solar Max was deployed from a Delta expendable launch vehicle, following launch from Cape Canaveral Air Force Station, FL, February 14, 1980.

It was the first satellite designed specifically to study the most violent aspect of solar activity—flares.

However, after eight months of successful operation, three small fuses in the SMM attitude control subsystem module failed. This left the satellite helpless to point precisely at targets of observation on the Sun, incapacitating four of its seven scientific instruments and compromising three others.

The first satellite designed for the study of solar flares was also the first of a new breed—built of standardized, modular components that can be replaced or repaired in space. Fortuitously, the ailing attitude control module was one of three replaceable, box-like units that are responsible for power, data handling and spacecraft positioning. These units form a Multimission Modular Spacecraft (MMS) system designed to support an attached payload of scientific instruments.

The planning for the capture and repair of the satellite began as controllers at NASA/Goddard Space Flight Center, Greenbelt, MD relayed the commands to hold Solar Max in orbit.

STS 41-C shaped up as a pivotal mission for NASA—the "proof of the pudding" for the Space Shuttle's capacity for orbital repair and servicing—with the future of long-lived satellites and extended space operations hanging in the balance.

The Challenger launch occurred Friday, April 6, 1984 from Kennedy Space Center, FL.

Solar Max—Rendezvous and Failure

Early Sunday morning on April 8, 1984, the Challenger crew got the word from Mission Control Center, Houston, TX that the rendezvous with Solar Max was at hand.

Using a star tracker to acquire the satellite's position, the astronauts got a Shuttle radar "lock-on" when Challenger was about 60 miles (100 kilometers) away.

Approximately two hours later, they had the spacecraft in sight. The retrieval attempt began as Mission Specialist Dr. George D. Nelson executed a 10-minute, 200-foot (60 meters) EVA. As his helmet-mounted camera recorded the action, Nelson matched the satellite's rotation rate (1 degree per second, counterclockwise, with a 15-degree wobble every six minutes).

Nelson made three attempts to attach the docking device to Solar Max but each time he failed to get the device to clamp onto the satellite.

With Nelson's Manned Maneuvering Unit (MMU)—a jet-propelled back pack—running low on propellant, Nelson was told by Commander Crippen to return to the Shuttle.

NASA elected at this point to grapple Solar Max with the Remote Manipulator System (RMS) or remote arm. But because of the random motion of the satellite, the crew made four futile attempts at capture.

Evaluating its options, NASA decided that the best solution was in the hands of Goddard Space Flight Center controllers. The mission: stabilize Solar Max via ground commands from Goddard and then try for capture again by use of the Shuttle's remote arm.

The drama of the rescue heightened as time became crucial: Goddard estimated that Solar Max's batteries would be dead in no more than eight hours, after which the satellite would have to be brought back home for a complete overhaul or abandoned in space.

A three-hour try by Goddard controllers at stabilizing the spacecraft through commands to its gyros failed, as the ground team realized that Solar Max's erratic motion had caused its gyros themselves to tumble and be unresponsive to commands.

It was then that NASA opted for its last-ditch effort: use of a computer program—known as the B-dot mode—to command the satellite's magnetic torquers rather than its gyros. Using the Earth's magnetic field, the torquers slow down the satellite's momentum in all three axes.

The tactic worked: Solar Max began to lose momentum and the ground team powered down the spacecraft, turning off every unnecessary source drawing on its battery life.

At one point, Goddard controllers even turned off the satellite's transmitters, a move that also eliminated data on the health of the spacecraft.

The B-dot technique ultimately slowed the motion of Solar Max, letting it gain new life from the Sun and setting the stage for another rendezvous and capture attempt.

Solar Max—Rendezvous and Success

In the early morning hours of April 9, the Goddard ground control team—after spending the night in a desperate race to "freeze" the Solar Max—found itself spinning up the satellite to .5-degree rate.

The plan was fixed: On Tuesday, April 10, the Challenger crew would again rendezvous with the satellite; perform a rotating grapple with the Shuttle's remote arm; and replace the satellite's attitude control system.

If all of this went well, and time permitting, the crew would even replace the main electronics box in one of Solar Max's science instruments, the coronagraph-polarimeter, prior to redeployment of the satellite.

With a second rendezvous approach much like the first, Challenger's Mission Commander, Capt. Robert L. Crippen, steered the orbiter to within 30 feet (9 meters) of Solar Max and Mission Specialist Hart began to extend the 50-foot (15.2 meters) remote arm.

A few anxious moments followed as Challenger passed out of Tracking and Data Relay Satellite (TDRS) range, cutting off communications between Challenger and Mission Control. However, within six minutes, Crippen communicated via the Australian ground station that, "we've got it (Solar Max), and we're putting it on the FSS." (The FSS is the Flight Support Structure, a berthing platform in the payload bay of the orbiter.)

In about an hour, Solar Max was securely attached to the FSS. The crew then tilted the berthing ring about 25 degrees forward and rotated the captured satellite—avoiding a collision of its solar arrays with the orbiter's tail and allowing for easy removal of the spacecraft's Attitude Control Subsystem.

With the Solar Max checked out and space suits recharged for the next day's EVA, the crew turned in before their early morning repair duties began.

Solar Max—the Repair

It was now Wednesday, April 11.

The EVA repair of Solar Max was the job for Mission Specialists Nelson and van Hoften.

Once in the orbiter's payload bay, van Hoften slipped his boots into the brackets attached to the remote arm's manipulator foot restraint and Hart—inside the orbiter on the flight deck—steered the arm and van Hoften to the faulty module.

In the meantime, Nelson had fitted himself in a foot restraint attached to the FSS itself.

Both Nelson and van Hoften were tethered to cables along the orbiter payload bay.

With Nelson assisting, van Hoften—in the period of an hour—had removed the faulty module, and replaced it with a new one. In a separate procedure of about four minutes, van Hoften improved the operation of one of Solar Max's instruments by snapping a protective cover over its vent to shield it from interference.

Still locked into the remote arm's foot restraint brackets, van Hoften tackled the more delicate task of removing the main electronics box on the satellite's coronagraph-polarimeter instrument, one not designed to be repaired in space.

Now, Nelson changed places with van Hoften and rode the arm up to install the new main electronics box on the instrument.

The removal-replacement job, which had taken more than two hours to complete during simulated pre-mission training sessions, had been done in only 45 minutes in the actual space environment.

Nelson and van Hoften moved away and watched as Solar Max was turned on again, tilted forward and rotated on the berthing ring. Later, Hart moved the remote arm to grapple Solar Max, unberth it, and suspend it outside the payload bay on the arm.

The seven-hour, 18-minute space walk by Nelson and van Hoften was the second longest in U.S. spaceflight history.

Solar Max—Alive Again and Well

On Thursday, April 12, Solar Max was pointed toward the Sun and deployed from the Challenger, to orbit Earth normally for the first time in three years.

This historic rendezvous, capture and repair mission earned the Challenger crew the unofficial title of "Ace Satellite Repair Company."

Spacecraft Description/Payload—The Solar Maximum Mission observatory is a 5,100-pound (2310 kilograms) satellite, managed by Goddard Space Flight Center, Greenbelt, MD for the investigation of the physics of solar flares.

The spacecraft is approximately 13 feet (4 meters) in length, 7 feet (2.3 meters) in diameter and modular in design. The upper 7 feet (2.3 meters) is the instrument module which houses all solar observation instruments and the Fine Pointing Sensor System for aiming control.

Below the instrument module is the Multimission Modular Spacecraft, a 5-foot (1.5 meter) triangular framework which houses the essential attitude control, power, communications and data handling systems.

Two fixed solar paddles are attached to a transition adaptor between the upper instrument module and the lower spacecraft bus. The paddles supply power to the spacecraft during the daylight portion of orbits, while three rechargeable batteries supply power at night.

The Solar Max carries the following scientific instruments: Gamma Ray Spectrometer; Hard X-ray Spectrometer; Hard X-ray Imaging Spectrometer; Soft X-ray Polychromator; Ultraviolet Spectrometer/Polarimeter; High Altitude Observatory Coronagraph/Polarimeter; and Solar Constant Monitoring Package.

Other Payloads—

- Cinema 360 Camera. This was its second of three scheduled flights. Mounted in the cargo bay, this 35mm camera recorded the historic rescue mission through its fisheye lens. Cinema 360 is a consortium of four planetariums, located in Tucson, AZ; Jackson, MS; Reno, NV; and Chicago, IL.

- IMAX Camera. Provided by IMAX Corporation, this camera recorded Challenger events on 70mm film.

- Shuttle Student Involvement Project (SSIP) Experiment. This was developed by a 19-year-old student to study the honeycomb structure built by bees in zero gravity. Honeywell, Inc., Minneapolis, MN, sponsored the project and provided technical support.

- Long Duration Exposure Facility (LDEF). This large cylindrical payload carried 57 separate experiments involving more than 200 investigators from the U.S. and eight other countries. The experiments were furnished by government laboratories, private companies and universities. The LDEF was deployed on Flight Day Two. It was designed, built and managed by Langley Research Center, Hampton, VA.

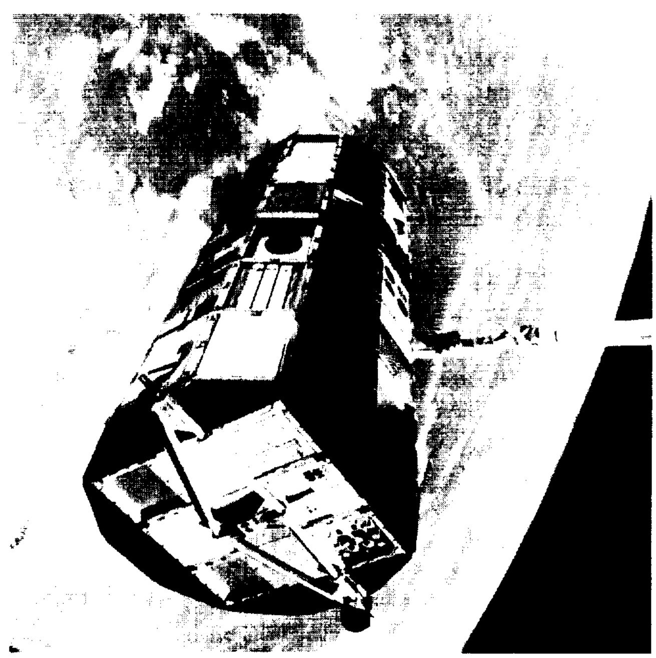
Project Results—STS 41-C was launched April 6, 1984 from Kennedy Space Center, FL. The orbiter altitude was 250 nautical miles (463 kilometers) at an orbital inclination of 28.5 degrees. Landing was at Kennedy Space Center, FL on April 12.

This mission marked the first repair of a satellite in orbit, first direct insertion ascent, and first flight of the Long Duration Exposure Facility.

Contractors

Rockwell International, Downey, CA	Orbiter
Martin Marietta, Denver, CO	MMU
Fairchild Weston Systems, Inc., Syosset, NY	Helmet Camera
Honeywell, Inc., Minneapolis, MN	SSIP
IMAX Systems, Inc., Toronto, Canada	IMAX Camera

Two STS 41-C mission specialists—George D. Nelson, right, and James D. van Hoften—use the mobile foot restraints and the remote manipulator system (RMS) as a "cherry picker" device for moving about as they perform repairs on the captured Solar Maximum Mission Satellite.



This onboard photograph shows the remote manipulator system (RMS) holding the Long Duration Exposure Facility (LDEF) suspended high above the Gulf of Mexico prior to releasing it into space.

INTELSAT V (F-9)

Launch Vehicle—Atlas Centaur, General Dynamics/Convair, San Diego, CA.

Program Overview—The International Telecommunications Satellite Organization (INTELSAT), with headquarters in Washington, DC, was created on August 20, 1964 through the adoption of interim agreements signed by 11 countries for the establishment of a global commercial communications satellite system.

Since February 12, 1973, INTELSAT has operated under definitive agreements with an organizational structure consisting of: (a) an Assembly of Parties (governments that are parties to the INTELSAT agreement); (b) a Meeting of Signatories (governments or their designated telecommunications entities that have signed the Operating Agreement); (c) a Board of Governors; and (d) an Executive Organ, headed by a Director General.

The Board of Governors, which has overall responsibility for the decisions relating to the design, development, construction, establishment, operation, and maintenance of the INTELSAT space segment, currently is composed of 29 governors (as of 10/88) from 116 countries and territories.

The INTELSAT global satellite system is comprised of two essential elements: the space segment, consisting of satellites owned by INTELSAT, and the ground segment, consisting of Earth stations owned by telecommunications entities in the countries in which they are located.

At present, the space segment consists of 14 satellites in synchronous orbit at an altitude of 22,240 statute miles (35,780 kilometers). The satellites are located over the Atlantic, Indian and Pacific Ocean regions.

The ground segment of the global system consists of more than 800 communications antennas and more than 600 Earth station sites in 110 countries and territories

Project Objectives—To position the INTELSAT satellite into its planned geostationary orbit in an operational status.

Spacecraft Description—Contributions were made to the design, development and manufacture of INTELSAT V by aerospace manufacturers around the world under the prime contractor, Ford Aerospace and Communications Corporation (FACC) of the United States. Members of the international manufacturing team included Aerospatiale (France), GEC-Marconi (United Kingdom), Messerschmitt-Bolkow-Blohm (Federal Republic of Germany), Mitsubishi Electric Corporation (Japan), Selenia (Italy), and Thomson-CSF (France).

Specific areas on which the individual manufacturers concentrated were:

Aerospatiale—Initiated the structural design that formed the main member of the spacecraft modular design construction.

GEC-Marconi—Produced the 11-GHz beacon transmitters used for Earth station tracking.

Messerschmitt-Bolkow-Blohm—Designed and produced the satellite's control subsystem and the solar array.

Mitsubishi—Was responsible for both the 6-GHz and the 4-GHz Earth coverage antennas. It also manufactured the power control electronics and, from an FACC design, the telemetry and command digital units.

Selenia—Designed and built the six telemetry, command and ranging antennas, two 11-GHz beacon antennas and two 14/11-GHz spot beam antennas. It also built the command receiver and telemetry transmitter, which combined to form a ranging transponder for determination of the spacecraft position in transfer orbit.

Thomson-CSF—Built the 10-w, 11-GHz traveling wave tubes of which there were 10 per spacecraft.

Dimensions of the spacecraft were:

Solar Array (end to end)	51.1 ft (15.6 meters)
Main Body "Box"	5.4 x 6.6 x 5.8 feet (1.6 x 2.0 x 1.7 meters)
Height	21 ft (6.4 meters)
Width (fully deployed)	22.25 ft (6.8 meters)
Weight (at launch)	4,252 pounds (1,928 kilos)

Spacecraft Payload—INTELSAT had the capacity for 12,000 two-way telephone circuits and two television channels.

Project Results—Atlas-Centaur 62, carrying the ninth INTELSAT payload, was launched from the Eastern Space and Missile Center (ESMC) Complex 26B on June 9, 1984, at 7:03 p.m. EDT. The Atlas booster and sustainer phases of flight were normal; however, a significant leak occurred in the Centaur liquid oxygen tank at the time of Atlas and Centaur separation. The resulting loss of liquid oxygen through the tank opening then precipitated a series of problems that compromised vehicle performance and resulted in the loss of the mission.

A team of investigators found the most probable cause of the failure was due to shock-induced loads on the liquid oxygen tank at high tank pressures.

INTELSAT Team:

INTELSAT

Director, Engineering Division	Emeric Podraczky
Manager, Launch Vehicle Program Office	Allan M. McCaskill

NASA Headquarters, Washington, DC

Acting Associate Administrator for Space Flight	Jesse W. Moore
Director, Space Transportation Support	J. B. Mahon
Atlas-Centaur Manager	F. R. Schmidt

Kennedy Space Center, FL

Director, Expendable Vehicles Operations	Charles D. Gay
Chief, Centaur Operations Division	James L. Womack
Chief, Automated Payloads Division	Donald G. Sheppard
INTELSAT Spacecraft Coordinator	Larry F. Kruse

Lewis Research Center, Cleveland, OH

Deputy Manager, Atlas-Centaur Project Office	John W. Gibb
Mission Project Engineer	Richard E. Orzechowski

Prime Contractors	Responsibility
Ford Aerospace and Communications Corporation Palo Alto, CA	INTELSAT V spacecraft
General Dynamics/Convair San Diego, CA	Atlas-Centaur vehicle
Honeywell Aerospace Division, St. Petersburg, FL	Centaur Guidance Inertial Measurement Group
Teledyne Systems Company, Northridge, CA	Digital Computer Unit/ Telemetry

STS 41-D/
SBS-D
SYNCOM IV-2
TELSTAR 3-C
OAST-1

Launch Vehicle—Space Transportation System (STS)—Space Shuttle Discovery, built by Rockwell International, Downey, CA.

Program Overview—See previous Shuttle missions.

Project Objectives—This was the first flight of Discovery. The STS 41-D and STS 41-F missions were cancelled on July 12, 1984 and combined in a revised 41-D mission.

The primary objectives of the revised mission were to deploy the Satellite Business System D (SBS-D) satellite on Flight Day One, the Syncom IV-2 on Flight Day Two, the TELSTAR 3-C satellite on Flight Day Three and to operate the Office of Aeronautics and Space Technology-1 payload on Flight Day Three through Flight Day Six. In addition, the crew was to conduct operations with the Radiation Monitoring Equipment (RME), Continuous Flow Electrophoresis System (CFES III) and the IMAX camera at various times during the six-day mission.

Flight crew for STS 41-D was Henry W. Hartsfield, Jr., Commander; Michael L. Coats (Cmdr.-USN), Pilot; Richard M. Mullane (Maj.-USAF), Steven A. Hawley, Ph.D, and Judith A. Resnik, Ph.D., Mission Specialists; and Charles D. Walker, McDonnell Douglas Corp., Payload Specialist.

Spacecraft Payload—

- CLOUDS. The CLOUD was a USAF photography experiment for taking Earth photographs of cloud cover dynamics and morphology over selected areas.

- SATELLITE BUSINESS SYSTEM (SBS-D/PAM-D). The SBS spacecraft provides an all-digital domestic communication system serving large industry, government and other users. The SBS communications spacecraft was placed in geosynchronous orbit by a Payload Assist Module-Delta class (PAM-D) and associated airborne equipment.

- Hughes Communications Service, Inc. Satellite (Syncom IV-2/UNO). The Syncom is a geosynchronous communications satellite. The spacecraft contains all propulsion systems necessary to attain geosynchronous equatorial orbit. A total of four Syncom IV spacecraft are planned to be launched over a two-year period. This was the first Syncom satellite flown by NASA.

- AT&T TELSTAR (TELSTAR 3-C/PAM-D). The TELSTAR is a spin-stabilized telecommunications satellite of American Telephone and Telegraph Company (AT&T). The TELSTAR was built by Hughes Aircraft Company with McDonnell Douglas providing the PAM-D upper-stage booster. The TELSTAR satellites transmit voice, video, and data in C-band using 24 transponders to receivers in the continental United States, Alaska, Hawaii, and Puerto Rico.

- Office of Aeronautics and Space Technology-1 (OAST-1). The Office of Aeronautics and Space Technology-l (OAST-1) was a payload containing three experiments mounted onto a Mission-Peculiar Equipment Support Structure (MPESS). The three experiments included the following: (1) Solar Array Experiment (SAE), which consists of an extendable Solar Array wing with the capability of extensions to about 100 feet (30 meters); (2) Dynamic Augmentation Experiment (DAE), a structure containing sensor and electronics packages; and (3) Solar Cell Calibration Facility (SCCF), a self-contained, data acquisition and storage and temperature control package.

  The SAE was unfolded from its container in the payload bay to a length of 73.5 feet (22 meters) (70 percent extended) and 105 feet (100 percent extended) and used for dynamic and thermal testing. The dynamics tests consisted of a quiescent array excited by Vernier Reaction Control System (VRCS) pulses. The amount of tip deflection was measured using the orbiter CCTV cameras and/or a Dynamic Augmentation Experiment (DAE), which uses a low-power laser.

  The crew extended and retracted the array, input the VRCS pulses, operated the cameras, and provided monitoring of the array's stability.

  The SCCF will be used to determine the validity of balloon flight solar cell calibration and laboratory-generated solar cell temperature coefficients. The SCCF is self-contained and requires minimal crew interface.

- Continuous Flow Electrophoresis Systems (CFES). The CFES payload originated from McDonnell Douglas Astronautics Company, St. Louis, MO., and included a fluid systems module, an experiment control and monitoring module, a sample storage module and a pump/accumulator. package, along with miscellaneous equipment stowed in a standard storage locker. The experiments were flown in the middeck, and a payload specialist activated, monitored, and controlled the operation of the CFES.

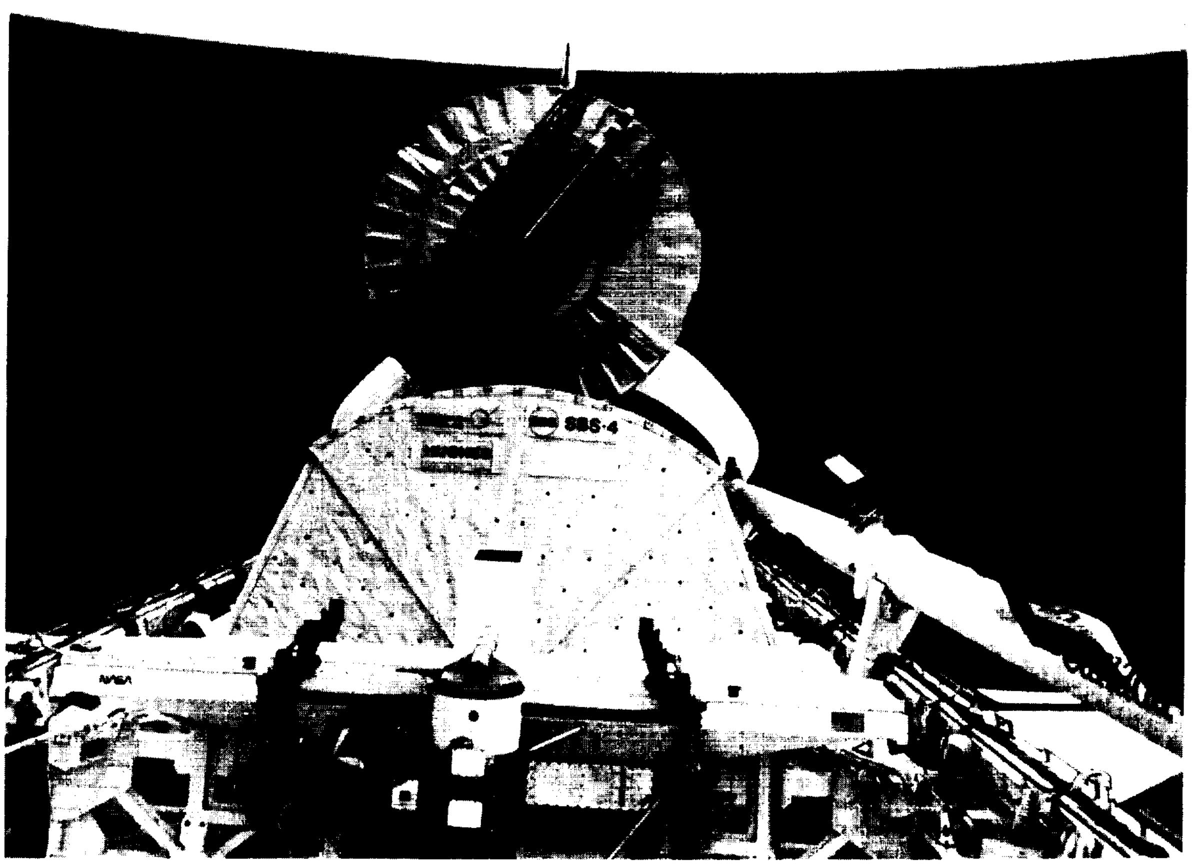
- IMAX. The IMAX camera was part of an agreement between NASA, the Smithsonian Institution, and IMAX Systems Corp. of Toronto, Canada, to produce a color motion picture film video of Shuttle flight operations from launch to landing. One 70mm motion picture camera was stowed with several lenses, two loaded film magazines, and five rolls of reloaded film in the middeck.

- Radiation Monitoring Equipment (RME). The RME experiment was designed to measure radiation levels in the orbiter middeck at various times throughout the flight. Experiment equipment included a hand-held Radiation Monitor (HRM-III), a gamma and electron dosimeter, and a pocket radiation meter (PRM).

- Student Experiment. The student experiment was the "Purification and Growth of Single Crystal Gallium by the Float Zone Technique in a

Zero Gravity Environment (SE 82-14)." This experiment, by Shawn P. Murphy, was sponsored by Rockwell International, Downey, CA. For this experiment, a single crystal of gallium doped with thallium was grown in space and compared to a crystal grown on Earth in an identical manner. In the absence of gravity, a more uniform distribution of the thallium and a more perfect gallium crystal was expected to result.

Project Results—The mission began from Kennedy Space Center at 8:41 a.m. EDT on August 30, 1984 and ended on touchdown at Edwards Air Force Base, CA, at 9:37 a.m. on September 5, 1984. Mission elapsed time was six days, 56 minutes. The orbit was 184 statute miles (296 kilometers) with an inclination of 29.45 degrees and a period of 90 minutes.



This onboard scene from STS 41-D shows the Syncom IV (Leasat-2) satellite as it begins to separate, à la frisbee, from the Shuttle's cargo bay.

Launch of the revised mission had been planned for August 29, but was delayed one day to evaluate a problem in the orbiter's Master Events Controller software. The launch was rescheduled for 8:35 a.m. EDT on August 30, but was delayed six minutes, 50 seconds because of an intrusion of a small two-engine aircraft into the range safety warning airspace.

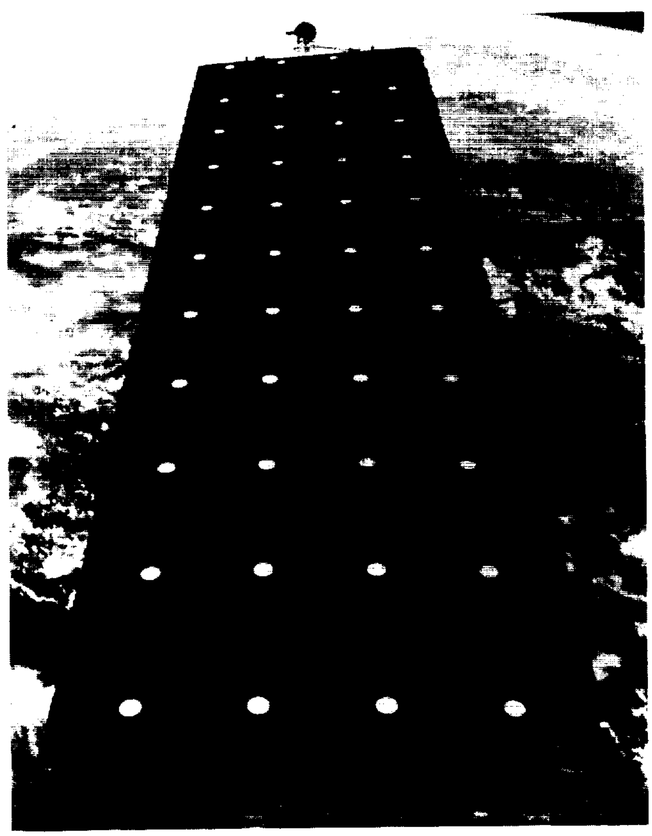
Both sets of Solid Rocket Booster parachutes deployed successfully. Booster structural damage was less than normal. The boosters, their frustrum and all main parachutes were recovered.

The SBS/PAM-D payload was released from the payload bay on schedule at approximately 4:40 p.m. on August 30. The PAM-D burn was successful. The Syncom IV-2 was released at approximately 9:16 a.m. EDT on August 31, as scheduled. The TELSTAR 3 payload was released at approximately 9:24 a.m. EDT on September 1.

On September 2, ice began to build up on the exterior of Discovery at the supply water dump nozzle. On September 3, the Remote Manipulator System (RMS) was used to perform a television survey of the ice and to observe a waste water dump. An ice column began forming shortly after the waste water exited its nozzle, so the dump was terminated. The total ice formation was then about 24 inches long and weighed from 10 to 28 pounds. After side-to-Sun attitude during the crew sleep period reduced the ice by only six inches and the firing of the Primary Reaction Control System thrusters did not shake it loose, a decision was made to use the RMS to dislodge the ice.

On September 4, most of the ice was broken off with the RMS. The OAST-1 solar array, the largest structure ever deployed in space, proved to be more stable than expected. This permitted the crew to perform the solar array tests in less time than planned and to accomplish other tests.

Due to malfunctions of the CFES equipment, Charles Walker was able to process only 70 to 80 percent of the material planned.



Late on its third day in orbit, the six-member crew of the Discovery began operations with this giant solar array experiment (SAE) panel. NASA's OAST-1 reached 100 percent extension on the second day of operations—Sept. 2.

Contractors

Rockwell International Downey, CA	Orbiter
Martin Marietta Denver, CO	MMU
IMAX Systems, Inc. Toronto, Canada	IMAX camera

GALAXY-C

Launch Vehicle—The Delta 176 rocket, a 3920/Payload Assist Module (PAM) version of the expendable launch vehicle consisting of the extended long-tank Thor booster with RS-27 engine, nine Castor IV strap-on motors and the Aerojet ITIP second stage, was used to launch the satellite. The spacecraft's perigee stage was the McDonnell Douglas PAM.

The propulsion subsystem consisted of the Thiokol Star 30B Apogee Kick Motor (AKM) and Reaction Control Subsystem. The solid propellant AKM is designed to accomplish the final orbit insertion and was an integral part of the spacecraft.

This was the eighth launch of the new Delta 3920 configuration and the fourth of the Delta 3920/PAM configuration. Overall, the Delta 3920 was 116 feet (35.5 meters) long including the spacecraft shroud. Lift-off weight was 415,990 pounds (189,087 kilograms).

Project Objective—The Galaxy-C satellite, owned by Hughes Communications, Inc., and built by the Hughes Aircraft Company's Space and Communications Group, was designed to relay video, voice, data and facsimile communications in the continental United States for large corporations, long-haul carriers, broadcasters, and point-to-multipoint transmission of commercial information from geosynchronous orbit.

The Galaxy-C was the last in the series of three Galaxy satellites.

Spacecraft Description—Galaxy-C was approximately 7 feet (2 meters) in diameter and 9 feet (3 meters) in length when stowed in the launch vehicle. It weighed 1,145 pounds (519 kilograms).

In orbit, the aft solar panel deployed, doubling the power output, and the antenna reflector erected for a combined height of nearly 22 feet (7 meters), or the equivalent of a two-story building. The solar array of K7 cells, which generated 19.7 milliwatts per square centimeter, produced 990 watts of DC power at beginning of life; two nickel cadmium batteries furnished power during solar eclipse. With a full load of station-keeping propellant stored on board it weighed 300 pounds (136 kilograms); it has a 10-year design life.

Spacecraft Payload—The satellite carried twenty-four 36-MHz channels, 12 vertically polarized and 12 horizontally polarized. Six spare traveling wave amplifiers provided the redundancy to increase transponder reliability.

The operations control center for the Galaxy satellites was located at Hughes Communications Headquarters in El Segundo, CA, with telemetry and command terminals in Fillmore, CA, and Brooklyn, NY.

Project Results—The payload was launched successfully from Pad 17B at the Eastern Space and Missile Center, Cape Canaveral Air Force Station, FL, at 6:18 p.m. EDT, on September 21, 1984. The spacecraft was placed in a stationary geosynchronous orbit 36,000 kilometers (22,300 statute miles) above the Equator at 93.5 degrees West Longitude.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	Jesse Moore
Associate Administrator for Space Tracking and Data Systems	Robert O. Aller
Chief, Expendable Launch Vehicle Programs	Peter Eaton
Delta Program Manager	Henry Clarks

Goddard Space Flight Center, Greenbelt, MD

Director	Dr. Noel W. Hinners
Deputy Director	John J. Quann
Director, Project Management	William C. Keathley
Deputy Director of Flight Projects	Robert C. Baumann
Delta Project Manager	William A. Russell, Jr.
Manager, Delta Mission Analysis and Integration	J. Donald Kraft
Galaxy Mission Integration Manager	Philip B. Frustace
Network Support Manager	Robert I. Seiders
Network Director	Ralph Banning

Kennedy Space Center, FL

Director	Richard G. Smith
Acting Director, Cargo Management and Operations	Wiley E. William
Director, Expendable Vehicles Operations	Charles D. Gay
Chief, Delta Operations Division	Wayne L. McCall
Head, Cargo Support Branch	Jim Weir
Spacecraft Coordinator	Arthur L. Sawyer

Contractors

McDonnell Douglas Astronautics Company Huntington Beach, CA	Delta Launch Vehicle and Payload Assist Module (PAM) Third Stage
Rocketdyne Division Rockwell International Canoga Park, CA	First Stage Engine (RS-27)
Morton Thiokol, Inc. Ogden, UT	Castor IV Strap-on Solid Fuel Motors
Aerojet Liquid Rocket Sacramento, CA	AJ10-118K (ITIP) Second Stage Engine
General Motors Corp. Delco Division Santa Barbara, CA	Guidance Computer

STS 41-G/

ERBS

Launch Vehicle—Space Shuttle Challenger, built by Rockwell International, Downey, CA.

Project Objectives—The primary objectives of this Challenger mission were deployment of NASA's Earth Radiation Budget Satellite (ERBS) and the conduct of the following experiments:

- NASA's Office of Space and Terrestrial Applications payload (OSTA 3)
- Large Format Camera (LFC)
- Orbital Refueling System (ORS)
- Canadian National Research Council's scientific packages (CANEX)
- Getaway Special Experiments (GAS)
- Radiation Monitoring Equipment (RME)
- Thermoluminescent Dosimeter (TLD)
- IMAX motion picture camera
- Auroral Photography Experiment (APE)

The crew of Challenger for STS 41-G was: Capt. Robert L. Crippen, USN, Commander; Cmdr. Jon A. McBride, USN, Pilot; Dr. Kathryn D. Sullivan, Dr. Sally K. Ride, and Lt.Cmdr. David C. Leestma, Mission Specialists; and Paul D. Scully-Power and Marc Garneau, of Canada, Payload Specialists.

Spacecraft Description/Payload—The ERBS, a spacecraft managed by NASA/Goddard Space Flight Center, Greenbelt, MD, was the platform for the most accurate measurements of their type ever made, confirming that clouds result in a net cooling of the Earth.

These measurements are serving as a baseline for climate modelers to determine whether clouds will partially offset or enhance a future warming of the Earth due to the "greenhouse effect"—a warming of the Earth's atmosphere and surface resulting from increased concentrations of gases, such as carbon dioxide, methane, nitrous oxide and chlorofluorocarbons.

The ERBS's three instruments are: Earth Radiation Budget Experiment (ERBE) Scanner and ERBE Non-Scanner, both designed to measure the components of the radiation budget and the solar constant; and the Stratospheric Aerosol and Gas Experiment II (SAGE II), which monitors the distribution of aerosols (small liquid or solid particles suspended in the air), ozone, water vapor, and nitrogen dioxide in the stratosphere.

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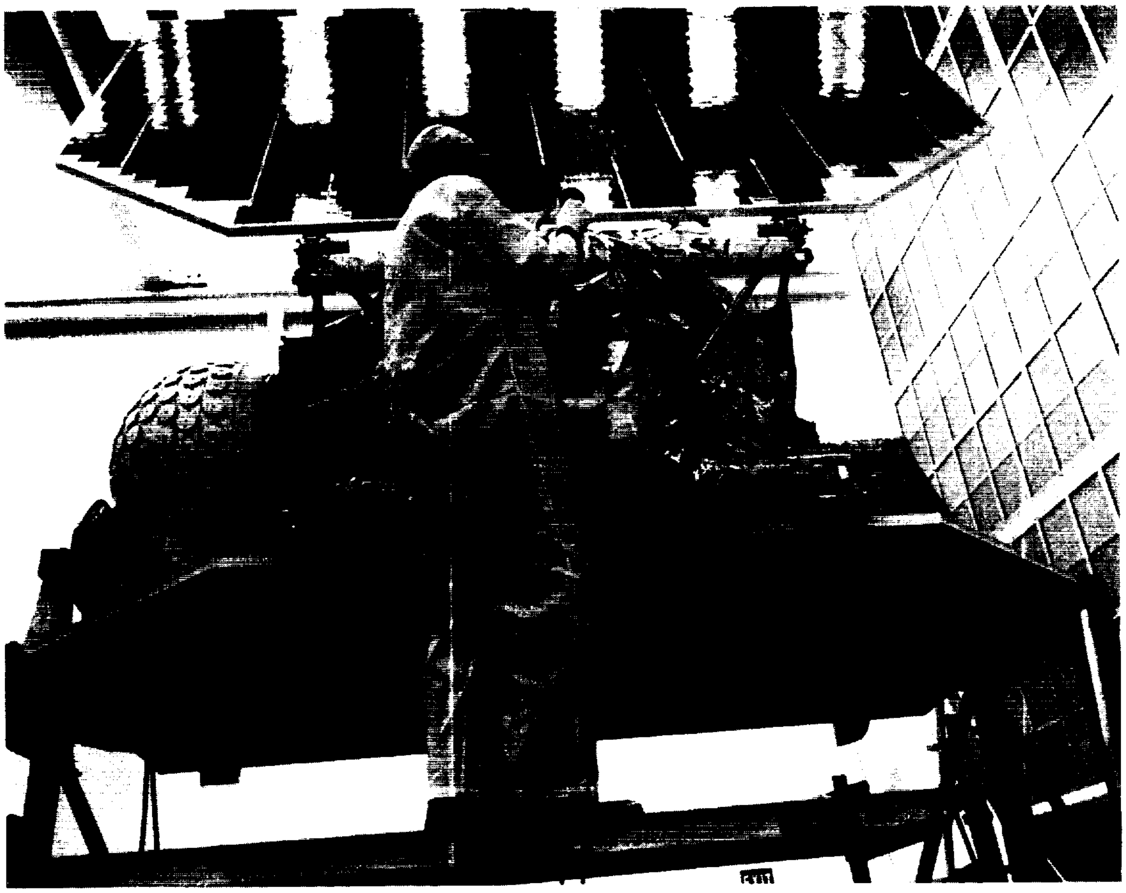
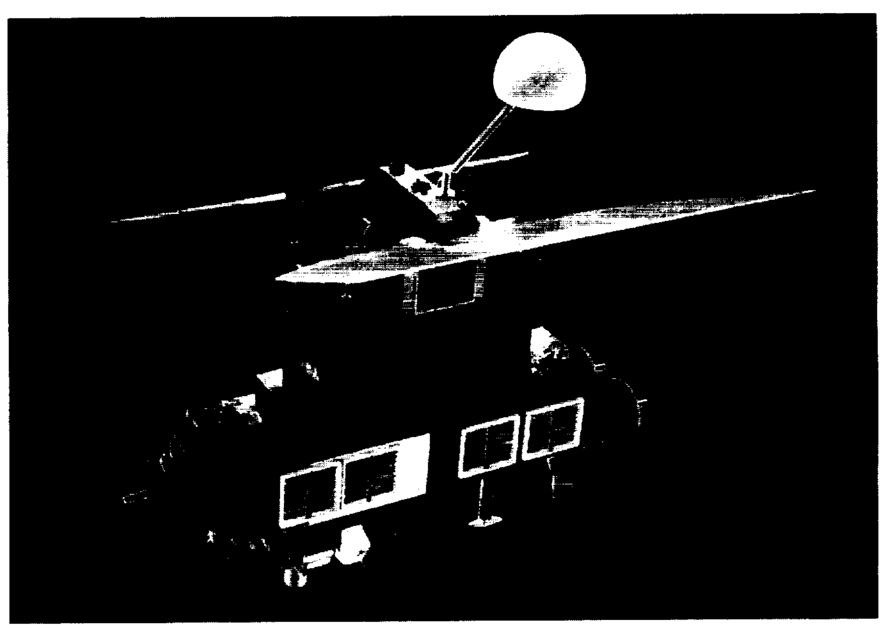


An engineer watches as one of the two large solar arrays on the Earth Radiation Budget Satellite is extended during preflight testing at Kennedy Space Center, FL.

An artist's concept shows the Earth Radiation Budget Experiment (ERBE) satellite in orbit.



1984

The 5,000-pound (2,300 kilogram) satellite was deployed by Challenger approximately nine hours after launch. Its four onboard thrusters then headed it for an operational orbit of 379 statute miles (610 kilometers).

Other Payloads—

- OSTA-3. This package consisted of three instruments: a modified version of the Shuttle Imaging Radar (SIR-B); Measurement of Air Pollution from Satellites (MAPS); and Feature Identification and Location Experiment (FILE). All of the instruments met their pre-mission objectives, except the SIR-B, which was severely impacted by the problems with the Challenger's KU-band antenna.

- SIR-B. The original plan was to obtain 42 hours of digital data to be analyzed by a science team of 43 investigators and 8 hours of optical data as backup. SIR-B actually acquired only 7-1/2 hours of digital data and 8 hours of optical data because of orbiter KU-band problems.

  This experiment encompassed investigations in a wide range of disciplines, including archeology, geology, cartography, oceanography and vegetation studies. Imaging radar produces photograph-like black-and-white images from data collected by transmitting millions of microwave radar pulses sequentially along a broad swath.

- MAPS. This experiment provided information as to what happens to industrial wastes after they enter the atmosphere, by measuring the distribution of carbon monoxide in the troposphere on a global scale. The MAPS sensor functioned nominally throughout the mission, collecting approximately 105 hours of data, 80 hours of which were considered excellent. The other 25 hours of data were impacted by the Flash Evaporator System problems, which caused fluctuations in the coolant loop temperature outside of the MAPS specification.

- FILE. The Feature Identification and Location Experiment was considered a complete success, acquiring imaged data over a wide range of environments. The FILE instrument imaged 240 scenes and successfully classified these scenes as snow/clouds, bare earth, water, or vegetation.

- LFC. The Large Format Camera was a near-perfect experiment. A total of 2,289 photographic frames were obtained. This 900-pound (440 kilogram) space eye can produce 2,400 negatives from 70 pounds (31 kilogram) of film, including two types each of black and white, and color. The first of its kind to orbit Earth, the LFC can capture scenes down to about 70 feet (21 meters) at 185 miles (298 kilometers) from Earth.

- ORS. The Orbital Refueling System. This was a demonstration of the capability to refuel orbiting satellites, once their thruster systems have depleted their fuel reserves. Mission Specialists Leestma and Sullivan performed the ORS demonstration in the aft end of the payload bay.

- CANEX. This was a cluster of 10 experiments conducted for the National Research Council (NRC) of Canada, comprising the categories of space technology, space science and life sciences.

  The objective of the space technology experiment was to aid in the development of a small optical measuring system to be used in space for rendezvous, inspection, and assembly tasks.

The space science experiments were directed to the areas of acid rain research, studies of the Earth's ozone layer, and effects of volcanic clouds on climate.

The life sciences experiments studied various aspects of the Space Adaptation Syndrome (SAS) which the Canadian payload specialist performed on himself.

Getaway Specials. Eight small, self-contained payloads were onboard Challenger:

- G007. Space Processing and Transmitting Computer Voice on Amateur Radio Bands. This experiment, sponsored by the Alabama Space and Rocket Center as an educational project, was comprised of three sub-experiments: one to study the solidification of lead-antimony and aluminum-copper alloys in a microgravity environment and compare the resulting crystalline structure and alloy strength with those of Earth-based equivalents.

  A second experiment investigated the growth of potassium tetra-cyanoplatinate hydrate crystals in an aqueous solution by an electrochemical method.

  The third experiment studied germination of radish seeds in low gravity and compared their growth characteristics with seeds grown on Earth.

- G0013. This was the Halogen Lamp Experiment (HALEX). Special optical radiation-type furnaces have been developed for material science research and processing in space. These furnaces rely on halogen lamps as heat sources. This experiment verified the use of halogen lamps during extended periods of microgravity.

- G0038. Vacuum Deposition (Art in Space). This computerized payload, designed by sculptor Joseph McShane of Prescott, AZ, became the first space art created in the weightless, vacuum environment of space.

- G0074. Zero-G Fuel System Test. This McDonnell Douglas Astronautics Company experiment provided data for designing more versatile lower-cost fuel tanks for future spacecraft.

- G0306. Trapped Ions in Space (TRIS). This experiment investigated the unexpectedly large flux of heavy ions (electrically-charged ions of oxygen and heavier atomic elements) that were first observed in an experiment onboard Skylab in 1973 and 1974.

- G0469. Cosmic Ray Upset Experiment (CRUX III). A joint, cooperative effort between NASA and IBM, CRUX III was the third in a series of flight experiments on the Space Shuttle to test for cosmic ray upset of microcircuits.

- G0518. Physics and Material Processing. This Utah State University study consisted of four experiments to record such processes as the activity of capillary waves and separation of flux and solder under zero-G conditions; test of fluid flow; and the observation of fluid flow patterns set up by a temperature difference.

- RME. Data were collected several times during the mission by the Radiation Monitoring Equipment to measure any gamma radiation exposure to the crew in the orbiter cabin.

- TLD. The Thermoluminescent Dosimeter was carried in a cabin locker to obtain cosmic radiation doses during space flight for comparison with the dosimetry systems current at the time of the mission.

- IMAX motion picture camera. Located in the mid deck of Challenger, this camera—a joint venture of NASA and IMAX, Inc., of Toronto, Ontario—produced a 70mm color film of orbiter launch, flight deck, payload bay and landing operations, suitable for viewing in IMAX-equipped theaters.

- APE. The Auroral Photography Experiment utilized a 35mm camera to photograph aurora and auroral optical effects on the orbiter through the aft flight deck windows.

Project Results—STS 41-G was launched at 7:03 a.m. (EDT) on October 5, 1984 from Kennedy Space Center, FL. Orbiter altitude was 190 nautical miles (352km) at an inclination of 57 degrees. Challenger landed at Kennedy Space Center at 12:26 p.m. (EDT) on October 13, 1984.

This Challenger mission was the first to include:

- Seven crew members

- A Canadian payload specialist

- Two women

- A spacewalk by an American woman

- A crewman flying a fourth Shuttle mission

- A demonstration of a satellite refueling technique in space

- A reentry profile crossing the eastern United States

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Science and Applications	Dr. B.I. Edelson
Deputy Associate Administrator for Space Science and Applications	S.W. Keller
Director, Space Science and Applications	Dr. S.G. Tilford
Deputy Director, Space Science and Applications	R.J. Arnold
ERBE Program Manager	D.S. Diller
ERBE Program Scientist	Dr. R.A. Schiffer

Goddard Space Flight Center, Greenbelt, MD

Director	Dr. N.W. Hinners
Director, Flight Project Directorate	W.C. Keathley
Project Manager	C. Wagner
Project Scientist	Dr. M. King

Langley Research Center, Hampton, VA

Director	Dr. D. Hearth
Office of Director of Projects	H. Wright
Project Manager	C. Woener
ERBE Experiment Manager	J. Cooper
ERBE Experiment Scientist	Dr. B. Barkstrom
ERBE Data Management Team Leader	J. Kibler
SAGE II Experiment Manager	W. Vaughan
SAGE II Experiment Scientist	Dr. M. McCormick
SAGE II Science and Data Manager	L. McMaster

Spacecraft Prime Contractor

ERBS	Ball Aerospace Systems Division, Boulder, CO

Instrument Contractors

ERBE Scanner	TRW, Inc., Redondo Beach, CA
ERBE Non-Scanner	TRW, Inc., Redondo Beach, CA
SAGE II	Ball Aerospace Systems Division, Boulder, CO

NOVA-III

Launch Vehicle—A four-stage Scout S-208 expendable launch vehicle was used to launch the NOVA-III spacecraft. The four stages of the Scout consisted of ALGOL IIIA, CASTOR IIA, ANTARES IIIA and ALTAIR IIIA motors.

Project Objective—NOVA-III was the third of a series of new generation, improved OSCAR navigation satellites, which are expected to satisfy the U.S. Navy's navigation satellite needs into the 1990's.

The NOVA spacecraft provide precise navigation data for any ship equipped with a relatively simple receiving set. A precise fix to an accuracy of a tenth of a mile can be obtained anywhere on the Earth's surface several times a day.

Spacecraft Description—The spacecraft weighed nearly 367 pounds (165 kilograms) and was designed to be inserted into an initial orbit of 213 statute miles (340 kilometers) by 460 statute miles (736 kilometers). The orbit was then to be circularized at 690 statute miles (1,104 kilometers) by the onboard orbit adjust transfer system.

The main structure of the spacecraft was an octagonal body 20.5 inches (52 centimeters) across and 15.5 inches (39 centimeters) high, topped by a cylindrical attitude control section 10.5 inches (26 centimeters) in diameter by 30 inches (76.2 centimeters) in length.

The satellite's transmitting system consisted of dual 5-MHz oscillators, phase modulators and transmitters operating at 400 MHz and 150 MHz. Dual incremental phase shifters were used to control oscillator offset.

An onboard computer was programmable from the ground and it had enough memory (262,144 bits in each half of the dual system) for storing a 5-day navigation message. Normal readout rate was 50 bits per second.

The power supply system was comprised of four panels covered with N/P solar cells, and one 12-ampere-hour battery pack containing 12 nickel-cadmium cells.

Attitude control systems provided for despin, magnetic stabilization, gravity gradient stabilization and magnetic spin despin. An extendable dual scissors boom, 18 inches (45 centimeters) long, located the disturbance compensation system at the center of mass of the satellite. A 26-foot (eight meter) extendable boom provided for gravity gradient stabilization.

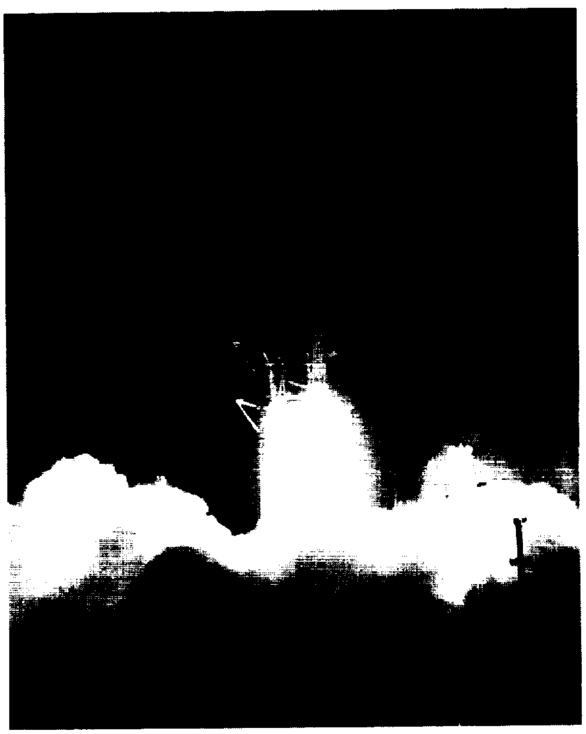
Spacecraft Payload—Although a single satellite in a circular polar orbit was sufficient to provide fix data at least twice a day, the Navy Navigation Satellite System provides almost hourly coverage by using a constellation of NOVA satellites in orbit.

The system has four tracking stations, several injection stations, a computing and control center, and shipboard receiver and computer systems. Twice a day, a data-injection package that will provide for the next 16 hours of operation is transmitted to the satellite and stored in its memory.

Project Results—Scout S-208 was launched at 6:43 p.m., PDT on October 11, 1984 from Vandenberg Air Force Base, CA. The NOVA-III payload was successfully placed in a circular near-polar orbit with an altitude of 201 statute miles (322 kilometers), 742 statute miles (1,197 kilometers) apogee, 713 statute miles (1,151 kilometers) perigee and orbit inclination of 89.8 degrees.

Scout S-208 was the 77th successful launch out of 81 since the initiation of the Scout recertification program. It was the 140th NASA/DOD Scout to be launched and the 85th to be utilized for an orbital mission.

The Scout vehicle was managed by the Langley Research Center, Hampton, VA.



Scout vehicle S-208, carrying the NOVA-III satellite, rises from its launch pad at Vandenberg Air Force Base, CA.

STS 51-A/

TELESAT-H SYNCOM IV-1

Launch Vehicle—Space Shuttle Discovery, built by Rockwell International, Downey, CA.

Project Objectives—The primary objectives of this mission, the second for Discovery, were deployment of two satellites and the retrieval of two others.

The satellites to be deployed were the Canadian communications satellite Anik D2 (Telesat-H) and the Hughes Leasat 1 (Syncom IV-1) communications satellites. Both were destined for geosynchronous orbit.

To be retrieved by the Discovery crew were the Palapa B-2 and the Westar VI spacecraft. Although successfully deployed during STS 41-B in February 1984, these two satellites failed to reach geosynchronous orbit because of onboard propulsion failure. Instead, the satellites were left in unusable orbits about 600 miles (960 kilometers) from Earth.

The 51-A crew consisted of: Capt. Frederick H. (Rick) Hauck, USN, Commander; Cmdr. David M. Walker, USN, pilot; and three Mission Specialists, Dr. Joseph P. Allen, Dr. Anna L. Fisher, and Cdr. Dale A. Gardner, USN.

Spacecraft Description/Payloads—Anik D2 (Telesat-H). Built by Hughes Aircraft Company for Telesat Canada, Limited, this geosynchronous telecommunications satellite was built for a 10-year life span. It was designed to provide voice communications and television coverage to a trans-Canadian network of Earth stations. It was to have been Canada's third totally dedicated commercial telecommunications satellite to use the 12/14-GHz K-band frequencies. The satellite used a McDonnell Douglas Payload Assist Module (PAM), which is attached to the spacecraft and performs the conventional third-stage rocket function of insertion into a near-synchronous orbit.

Syncom IV-1. This spacecraft was built by Hughes Aircraft Company under contract with the U.S. Navy to provide leased VHF communications services to the Department of Defense for at least five years. Designed specifically for Space Shuttle deployment, the satellite completely spanned the payload bay.

Another feature of the spacecraft was an explosive device which, at the moment of deployment, released a spring that ejected the Syncom in a "frisbee" motion. This action gave the spacecraft its separation velocity and gyroscopic stability. The Syncom had its own unique upper stage to transfer it to geosynchronous orbit.

Palapa B-2/Westar. These two satellites were deployed during the STS 41-B mission of Challenger, following its February 3, 1984 launch from Kennedy Space Center, FL. As a result of the erratic burning of the Payload Assist Module (PAM) stages, both of these spacecraft failed to achieve geosynchronous orbits and remained in low elliptical orbits of approximately 185 nautical miles by 600 nautical miles (343 x 1,111 kilometers). Perigee kick motors then were fired to circularize the orbits to approximately 600 nautical miles (1,111 kilometers). (See "Project Results" for retrieval operations details.)

Other Payloads/Experiments—Diffusive Mixing of Organic Solutions (DMOS). This experiment by the Minnesota Mining and Manufacturing Company (3M) was a study of crystal growth kinetics. It marked the beginning of a larger program which was in the planning stages between the Company and NASA. The ultimate goal was the production of commercially valuable products in the fields of organic and polymer chemistry. Large organic crystals were grown utilizing diffusion, or random thermal agitation, as opposed to recrystallization from hot solutions.

The experiment successfully produced organic crystals of sufficient size to be characterized by optical diagnostic techniques. These crystals were studied by 3M for applications to the company's businesses in the areas of electronics, imaging and health care.

Radiation Monitoring Equipment (RME). This device was used to measure any gamma radiation exposure to the crew in the orbiter crew cabin. The experiment consisted of a hand-held radiation monitor and two pocket radiation exposure meters. Data were collected several times throughout the mission, with the meters being operated by the crew. On Shuttle landing, the data were provided to the U.S. Air Force Space Division for interpretation.

Project Results—STS 51-A (Discovery) was launched from Kennedy Space Center, FL at 7:15 a.m. (EST) on November 8, 1984. Changing wind direction caused wind shear at an altitude of 20,000 feet to 40,000 feet (6,000 to 12,000 meters) which necessitated a one-day launch delay.

The altitude was 160 nautical miles (296 kilometers), at an inclination of 28.45 degrees.

The Anik D2 (Telesat) satellite was deployed from Discovery on Flight Day Two, the Leasat 1 (Syncom IV-1) on Flight Day Three—both without incident.

In preparation for the retrieval of the two ailing satellites, Palapa B-2 and Westar, NASA had, by approximately October 23, 1984, maneuvered the spacecraft to 195-nautical-mile (361 kilometers) circular orbits. To allow for a two-spacecraft rendezvous, NASA placed them 10 degrees apart, a separation of approximately 600 nautical miles. (1,111 kilometers).

Palapa B-2 was retrieved on Flight Day Four, Westar on Flight Day Five. Both retrievals were highly successful. In fact, throughout the mission, the only problem which required considerable real-time replanning occurred on the EVA for Palapa. Mission Specialist Dale Gardner discovered during the EVA that he could not attach an adaptor bracket to the top of Palapa because of an obstruction on the satellite. As a solution, Mission Specialist Joe Allen manually positioned Palapa so that Gardner could attach the bracket to the bottom of the satellite.

The same procedure was followed for Westar on Flight Day Five.

This was a seven-day, 23-hour, 45-minute mission. Because of the delayed launch, the landing date at Kennedy's Runway 15 was delayed until 7:00 a.m. (EST) on November 16, 1984.

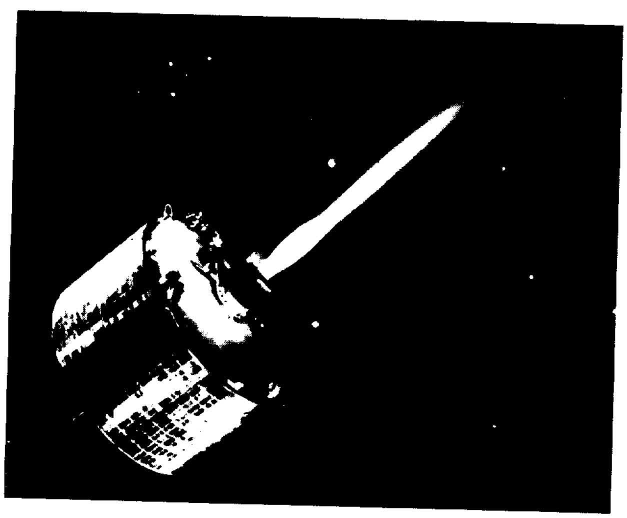
Major Participants—

NASA Headquarters, Washington, DC

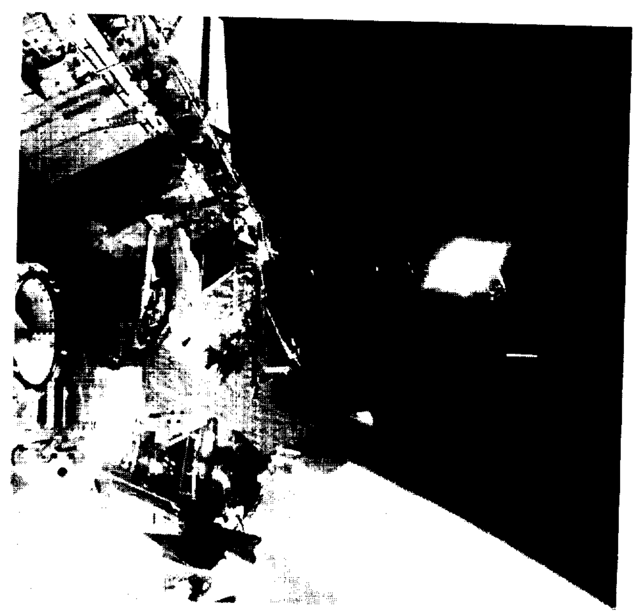
Associate Administrator for Space Flight	J.W. Moore
Associate Administrator for Space Science and Applications	B.I. Edelson
Director, Shuttle Payloads Engineering Division	M.J. Sander

3M Center, St. Paul, MN

Principal Investigator	W. Egbert
Co-Investigators	E. Cook
	D. Gerbi



This artist's concept depiction shows a Syncom satellite on orbit. Syncom IV-1 (Leasat 1) was successfully deployed from the Space Shuttle Discovery (STS 51-A), following launch from Kennedy Space Center, FL on November 8, 1984.



51-A ONBOARD SCENE—Astronaut Dale A. Gardner, left, hangs onto an adapter for securing the Palapa B-2 satellite in Discovery's cargo bay, while Astronaut Joseph P. Allen (background) takes a brief trip over to the work station on the Shuttle's port side. The two were about to complete the berthing exercises for the first of two scheduled retrievals on this eight-day flight.

NOAA-F

Launch Vehicle—U.S. Air Force Atlas E expendable launch vehicle, built by General Dynamics/Convair, San Diego, CA.

Program Overview—The NOAA-F weather satellite was the fifth NOAA-funded operational spacecraft of the TIROS-N (Television and Infrared Observation Satellite) weather satellites dating back nearly 25 years to the TIROS-1, launched on April 1, 1960. It was the sixth in the series of eleven satellites developed to give scientists the most comprehensive meteorological and environmental information since the start of the Nation's space program.

TIROS-N was the first in a series of third-generation operational environmental satellites. It was launched October 13, 1978 and was a research and development prototype for the operational follow-on series, NOAA-A through -G.

NOAA-F replaced NOAA-7 in orbit as the afternoon satellite, and was designated NOAA-9 upon its successful orbit.

Project Objectives—NASA's primary objectives for the NOAA-F mission were to launch the spacecraft into a Sun-synchronous orbit of sufficient accuracy to enable the spacecraft to accomplish its operational mission requirements, conduct an in-orbit evaluation and checkout of the spacecraft and, upon completion of this evaluation, turn the operational control of the spacecraft over to NOAA's National Environmental Satellite Data and Information Service (NESDIS).

The orbit would have a locator Equator crossing time of approximately 2:20 p.m. northbound and 2:20 a.m. southbound to permit regular and dependable daytime and nighttime meteorological observations in both direct readout and stored modes of operation in support of the Nation's operational environment satellite system.

In addition to meeting the NOAA mission requirements, a major NASA objective for this mission was to successfully acquire data from the Earth Radiation Budget Experiment (ERBE) instruments for application in scientific investigations aimed at improving our understanding of the processes which influence climate and climate change. Application of these data was the responsibility of the ERBE project.

Another NASA objective was to acquire data from the Solar Backscatter Ultraviolet (SBUV/2) instrument to determine stratospheric ozone concentrations on a global basis. These measurements will initiate a long-term program to detect trends in ozone concentrations related to anthropogenic and solar effects.

A joint NOAA/NASA objective was to continue the Satellite-Aided Search and Rescue (COSPAS/SARSAT) program which was initiated with the NOAA-E (8) mission. (COSPAS/SARSAT, with primary participation from Canada, France, the Soviet Union and the United States, makes use of satellites to rescue people from downed airplanes and ships in distress).

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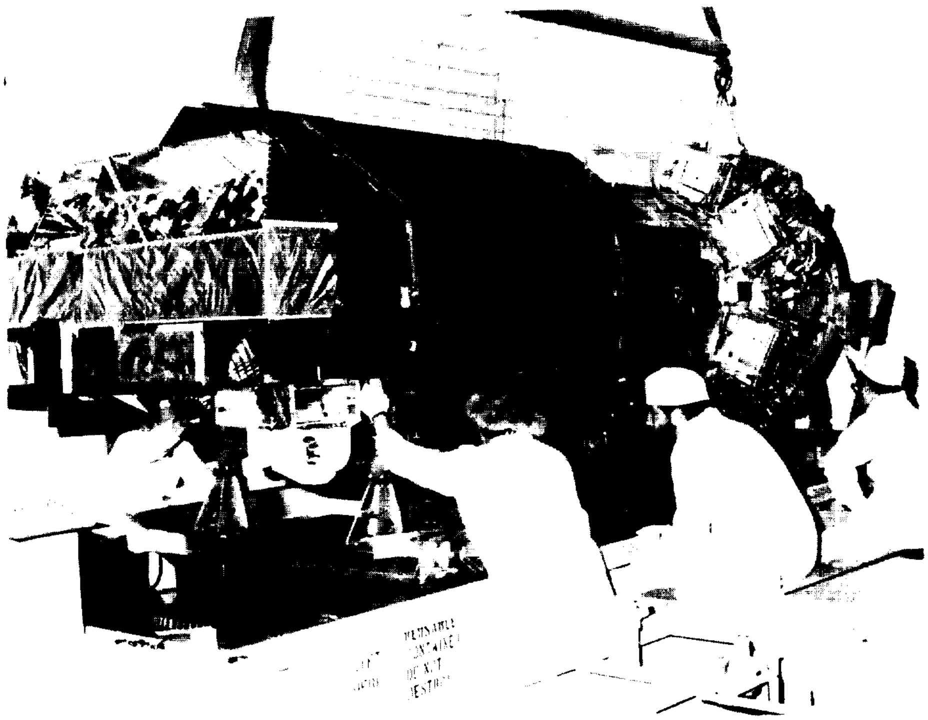


Technicians at RCA Astro-Electronics, Princeton, NJ, prepare an advanced TIROS-N weather satellite for shipment to Vandenberg Air Force Base, CA. The satellite was turned over to the National Oceanic and Atmospheric Administration and redesignated NOAA-9 when in orbit.

Spacecraft Description/Instrumentation—The physical characteristics of the NOAA-F spacecraft are:

The main body is 13.7 feet (4.18 meters) long, and 6.2 feet (1.88 meters) in diameter. The solar array is 7.8 by 16.1 feet (2.37 by 4.91 meters), for a total of 125 square feet (11.6 meters). At liftoff, the weight of the spacecraft was 3,775 pounds (1,712 kilograms); on orbit, 2,288 pounds (1,030 kilograms). The spacecraft was designed for a lifetime greater than two years.

The instrumentation onboard the NOAA-F spacecraft was:

- Advanced Very High Resolution Radiometer (AVHRR). This was a five-channel, cross-track scanning radiometer which produces digital image data in five spectral intervals in the visible, infrared, and near-infrared regions. Provided by International Telephone and Telegraph (ITT), the AVHRR is a single module mounted on the Earth-facing side of the spacecraft instrument mounting platform.

- TIROS Operational Vertical Sounder System (TOVS). This instrument cluster is used to determine radiance needed to calculate temperature and humidity profiles of the atmosphere from the Earth's surface to the upper stratosphere. It consists of three separate instruments:

  — High Resolution Infrared Radiation Sounder (HIRS/2). This instrument will measure radiation in 20 spectral regions of the infrared spectrum, including shortwave and longwave regions. It was built by ITT's Aerospace/Optical Division.

- Stratospheric Sounding Unit (SSU). Supplied by the United Kingdom's Meteorological Office, the SSU uses a selective absorption technique to make measurements in three channels.

- Microwave Sounding Unit (MSU). This instrument was provided by the Jet Propulsion Laboratory (JPL), Pasadena, CA. Its passive microwave measurements can be converted into temperature profiles of the atmosphere from the Earth's surface to 65,000 feet (20 kilometers).

• Space Environment Monitor (SEM). This is a multichannel charged-particle spectrometer, designed to provide measurements of the population of the Earth's radiation belts and of particle precipitation phenomena resulting from solar activity.

• Earth Radiation Budget Experiment (ERBE). The ERBE instruments consisted of a medium and wide field-of-view nonscanning radiometer and a narrow field-of-view scanning radiometer. These instruments were designed to measure Earth radiation energy budget components at satellite altitude; to make measurements from which monthly average Earth radiation energy budget components could be derived at the top of the atmosphere on regional, zonal and global scales; and to provide an experimental prototype for an operational ERBE instrument for future long-range monitoring programs. The ERBE was provided by TRW.

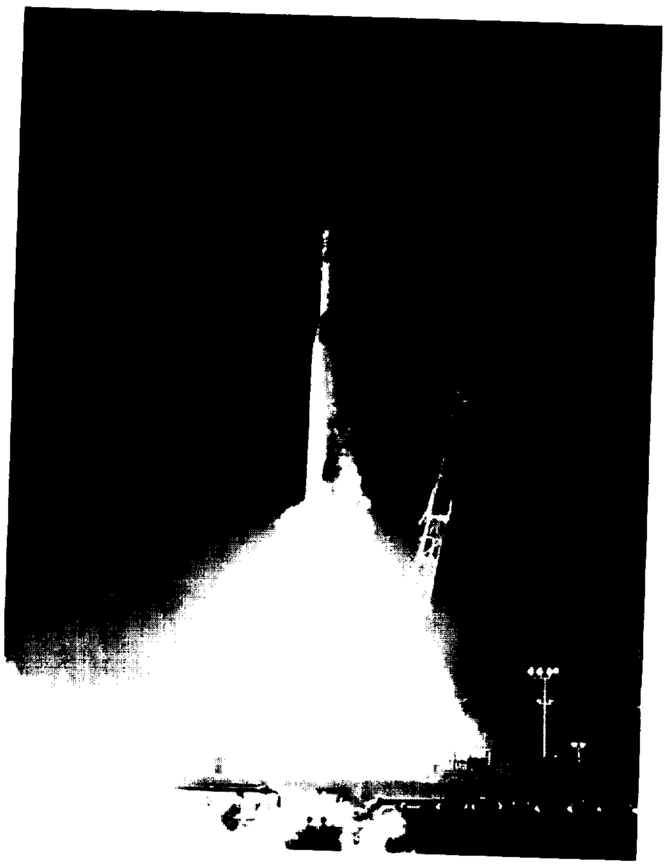
• Solar Backscatter Ultraviolet Spectral Radiometer, Mod 2 (SBUV/2). Provided by Ball Aerospace System, Boulder, CO. The SBUV/2 was a spectral scanning ultraviolet radiometer to be flown on the afternoon NOAA spacecraft. Its objectives are to make measurements from which total ozone concentrations in the atmosphere can be determined to an absolute accuracy of one percent.

• Argos Data Collection System. This system, provided by France, is a random-access system that provides a means for locating and/or collecting data from remote fixed and free-floating terrestrial and atmospheric platforms. Approximately 400 platforms will transmit data to the satellite. Information derived by the system will be transferred to the spacecraft and transmitted to Earth for additional ground data processing.

• Satellite-Aided Search and Rescue System (COSPAS/SARSAT). This is an international program participated in by Canada, France, the Soviet Union and the United States. This system onboard NOAA-F has the capability of detecting and locating existing emergency transmitters operating at 121.5 and 243 MHz, as well as experimental transmitters operating at 406 MHz. COSPAS/SARSAT instrumentation relays distress signals from downed aircraft and ships in distress to mission control centers in the United States, France, the Soviet Union and Canada for relay to the appropriate rescue coordination center.

Project Results—NOAA-F originally was scheduled for launch on November 8, 1984. Scrubbed 13 times—eight because of weather, five because of mechanical problems—NOAA-F finally was launched at 2:42 a.m. (PST) on December 12, 1984 from Space Launch Complex 3 (SLC 3) at Vandenberg Air Force Base, CA.

NOAA-F was launched into a 540-mile (870 kilometers), near-polar orbit with an inclination angle of 98.86 degrees to the Equator. The total orbital period was 102.12 minutes, with an average of 72 minutes in sunlight and 30 minutes in the Earth's shadow.



Launch of the NOAA-F weather monitoring satellite from Vandenberg Air Force Base, CA. The satellite was launched aboard an Air Force Atlas-E vehicle on December 12, 1984. Once it was evaluated in orbit, the satellite was designated NOAA-9. Procured and managed by NASA, the satellite was the sixth in a series of weather monitoring spacecraft for the National Oceanic and Atmospheric Administration.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	J.W. Moore
Associate Administrator for Space Science and Applications	B.I. Edelson
Director, Earth Science and Applications Division	S.G. Tilford
Manager, Operational Meteorological Satellite	J.R. Greaves

Manager, ERBS Program	D.S. Diller
Manager, Search and Rescue Program	T.E. McGunigal
Manager, Atlas-E Program	J.A.Salmanson
Director, Ground Networks Division	C.T. Force

Goddard Space Flight Center, Greenbelt, MD

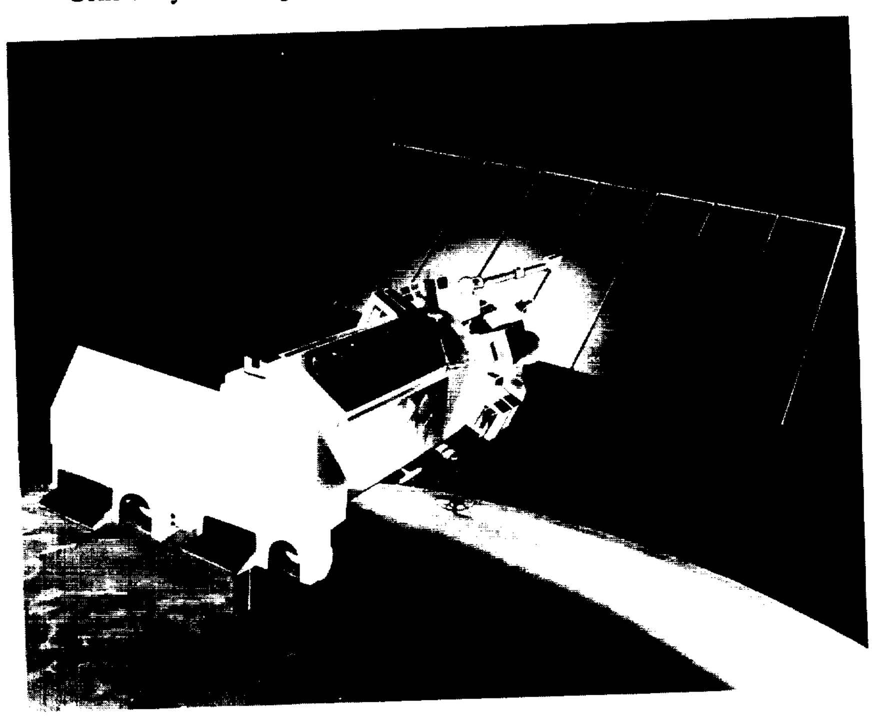
Director	N.W. Hinners
Metsat Project Manager	G.W. Longanecker
ERBE Project Manager	C.L. Wagner
Launch Vehicle Manager	J.F. Corrigan

National Oceanic and Atmospheric Administration (NOAA)

Assistant Administrator for NESDIS	J.H. McElroy
Deputy Assistant Administrator for Satellites	W.B. Bishop

Contractors

General Dynamics/Convair	Launch Vehicle
RCA Astro-Electronics Division	Spacecraft
General Electric	Guidance (radio command)
Rockwell International, Rocketdyne Division	Propulsion
Aerospace Corp.	General systems engineering



Artist's concept of the NOAA-F satellite in orbit.

1985
Missions

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INTELSAT V (F-10)

Launch Vehicle—Atlas Centaur, General Dynamics/Convair, San Diego, CA.

Program Overview—The International Telecommunications Satellite Organization (INTELSAT), with headquarters in Washington, DC, was created on August 20, 1964 through the adoption of interim agreements signed by 11 countries for the establishment of a global commercial communications satellite system.

Since February 12, 1973, INTELSAT has operated under definitive agreements with an organizational structure consisting of: (a) an Assembly of Parties (governments that are parties to the INTELSAT agreement; (b) a Meeting of Signatories (governments or their designated telecommunications entities that have signed the Operating Agreement; (c) a Board of Governors; and (d) an Executive Organ, headed by a Director General.

The Board of Governors, which has overall responsibility for the decisions relating to the design, development, construction, establishment, operation, and maintenance of the INTELSAT space segment, currently is composed of 29 governors (as of 10/88) from 116 countries and territories.

The INTELSAT global satellite system comprises two essential elements: the space segment, consisting of satellites owned by INTELSAT, and the ground segment, consisting of Earth stations owned by telecommunications entities in the countries in which they are located.

At present, the space segment consists of 14 satellites in synchronous orbit at an altitude of 22,240 statute miles (35,780 kilometers). The satellites are located over the Atlantic, Indian and Pacific Ocean regions.

The ground segment of the global system consists of more than 800 communications antennas and more than 600 Earth station sites in 110 countries and territories.

Project Objectives—To position the INTELSAT satellite into its planned geostationary orbit in an operational status.

Spacecraft Description—Contributions were made to the design, development and manufacture of INTELSAT V by aerospace manufacturers around the world under the prime contractor, Ford Aerospace and Communications Corporation (FACC) of the United States. Members of the international manufacturing team included Aerospatiale (France), GEC-Marconi (United Kingdom), Messerschmitt-Bolkow-Blohm (Federal Republic of Germany), Mitsubishi Electric Corporation (Japan), Selenia (Italy), and Thomson-CSF (France).

Specific areas on which the individual manufacturers concentrated were:

Aerospatiale—Initiated the structural design that formed the main member of the spacecraft modular design construction.

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GEC-Marconi—Produced the 11-GHz beacon transmitters used for Earth station tracking.

Messerschmitt-Bolkow-Blohm—Designed and produced the satellite's control subsystem and the solar array.

Mitsubishi—Was responsible for both the 6-GHz and the 4-GHz Earth coverage antennas. It also manufactured the power control electronics and, from an FACC design, the telemetry and command digital units.

Selenia—Designed and built the six telemetry, command and ranging antennas, two 11-GHz beacon antennas and two 14/11-GHz spot beam antennas. It also built the command receiver and telemetry transmitter, which combined to form a ranging transponder for determination of the spacecraft position in transfer orbit.

Thomson-CSF—Built the 10-w, 11-GHz traveling wave tubes of which there were 10 per spacecraft.

Dimensions of the spacecraft were:

Solar Array (end to end)	51.1 ft (15.6 meters)
Main Body "Box"	5.4 x 6.6 x 5.8 feet (1.6 x 2.0 x 1.7 meters)
Height	21 ft (6.4 meters)
Width (fully deployed)	22.25 ft (6.8 meters)
Weight (at launch)	4,252 pounds (1,928 kilos)

Spacecraft Payload—Had capacity for 12,000 two-way telephone circuits and two television channels.

Project Results—The INTELSAT V (F-10) spacecraft was successfully launched into geosynchronous orbit aboard an Atlas Centaur rocket at 6:55 p.m. (EST) on March 22, 1985.

<u>INTELSAT Team:</u>

INTELSAT

Director, Engineering Division	Emeric Podraczky
Manager, Launch Vehicle Program Office	Allan M. McCaskill

<u>NASA Headquarters, Washington, DC</u>

Acting Associate Administrator for Space Flight	Jesse W. Moore

Acting Associate Administrator for Space Flight	Jesse W. Moore
Director, Space Transportation Support	J. B. Mahon
Atlas Centaur Manager	F. R. Schmidt

<u>Kennedy Space Center, FL</u>

Director, Expendable Vehicles Operations	Charles D. Gay
Chief, Centaur Operations Division	James L. Womack
Chief, Automated Payloads Division	Donald G. Sheppard
INTELSAT Spacecraft Coordinator	Larry F. Kruse

<u>Lewis Research Center, Cleveland, OH</u>

Deputy Manager, Atlas Centaur Project Office	John W. Gibb
Mission Project Engineer	Richard E. Orzechowski

<u>Contractors</u>

Ford Aerospace and Communications Corporation Palo Alto, CA	INTELSAT V spacecraft
General Dynamics/Convair	Atlas Centaur vehicle
Honeywell Aerospace Division St. Petersburg, FL	Centaur Guidance Inertial Measurement Group
Teledyne Systems Company Northridge, CA	Digital Computer Unit/ Telemetry

STS 51-D/

TELESAT-1 SYNCOM IV-3

Launch Vehicle—Space Shuttle Discovery, built by Rockwell International, Downey, CA.

Program Overview—See previous Shuttle missions.

Project Objectives—The primary objectives of the five-day STS 51-D mission included the deployment of Telesat Canada's Anik C-1 (Telesat-1) communications satellite and the Hughes-built Syncom IV-3 satellite.

Karol J. Bobko, Col., USAF, was the mission commander, and Donald E. Williams, Cmdr., USN, was the pilot. The mission specialists were Dr. Jeffery A. Hoffman (Ph.D.), S. David Griggs, Capt., USNR, and Dr. M. Rhea Seddon (M.D.). Payload specialists were McDonnell Douglas engineer Charles D. Walker and Senator E.J. (Jake) Garn (R-Utah).

Spacecraft Description—The Telesat-1 weighed 2,394 pounds (3350.0 kilograms). It was perched atop its Payload Assist Module (PAM-D) kick stage.

Telesat-1 was the last of Telesat's trio of 14/12-GHz Anik C satellites. Telesat-1 was the first satellite placed in final orbit using Telesat's new global tracking antenna system.

The Syncom IV-3 weighed 2,394 pounds (6,889 kilograms).

Spacecraft Payload—Anik C communication satellites are identical, cylindrical, spin-stabilized spacecraft that operate exclusively in the "high frequency" (14- and 12-GHz) satellite radio bands, with 16 transponders (communication repeaters) each. Each of these 16 satellite channels is capable of carrying two color TV signals, together with their associated audio and cue and control circuits, for a total TV signal capacity of 32 programs per satellite. Anik C-3 and Anik C-2 currently are carrying Canadian pay television service, educational broadcasting and long-distance telephone and data traffic.

Syncom IV-3, a geosynchronous communication satellite built by Hughes Aircraft Company under contract with the Navy, was the third of four Syncom spacecraft scheduled for deployment from the Space Shuttle. Other Syncoms were deployed during the STS 41-D and STS 51-A missions.

Other Payloads—Other STS 51-D experiments included a reflight of the McDonnell Douglas Continuous Flow Electrophoresis system (CFES), flown earlier on STS-4 and STS-6.

Additional experiments were NASA's American Flight Echocardiograph (AFE), Protein Crystal Growth Experiment and Image Intensifier. Two Get Away Special (GAS) canisters carried on this flight contained Goddard Space Flight Center's Capillary Pump Loop (CPL) experiment and Japan's Asahi National Broadcasting Corp., Physics of Solids and Liquids.

Also carried on this flight were two student experiments: Statoliths in Corn Root Caps and the Effects of Weightlessness on the Aging of Brain Cells.

In addition, STS 5l-D astronauts conducted an informal science study: Toys in Space.

Project Results—The mission began at 8:59 a.m. EST on April 12, 1985 from Kennedy Space Center, FL. and ended at 8:54 a.m. EST on April 19, 1985 at Kennedy Space Center. The mission duration was six days, 23 hours and 55 minutes. Its orbital elements were 245 nautical miles (453 kilometers) apogee and 165 nautical miles (305 kilometers) perigee.

Telesat-1 spun up and out of Discovery's payload bay on April 12 at 23:38, midway through the seventh orbit. The solid propellant PAM fired perfectly at 00:23 to Telesat-1 on to a good geosynchronous transfer trajectory. Telesat-1 became the thirteenth satellite the Shuttle had successfully sent on its way to geosynchronous orbit.

Syncom IV-3 was deployed on Flight Day Two, April 13 but due to the failure of a sequencing switch to trip automatically, the spacecraft drifted lifeless in space. A rendezvous was planned to attempt to deploy the switch fully. In preparation for the rendezvous, the two devices—a "fly swatter" and "lacrosse stick"— were fabricated by the crew to snare the switch with the use of the Remote Manipulator System (RMS). On Flight Day Five, an Extra Vehicular Activity (EVA) was performed to attach the two devices to the RMS end effector. On Flight Day Six, the rendezvous was performed, and the RMS was positioned so that the fly swatter could be used to snare the switch. The switch was snared at least twice but the Syncom sequencer failed to operate. Syncom IV-3 remained inoperable until restarted by the crew of STS 51-I.

The Space Shuttle Discovery's remote manipulator system, with two jury-rigged attachments, moves toward the troubled Syncom-IV communications satellite in an attempt to trip a switch to activate the spacecraft.

Liftoff was delayed approximately 55 minutes—10 minutes due to a cargo ship in the launch safety area and 45 minutes for weather evaluation.

The mission was extended one day to afford the crew sufficient time to stow the cabin and prepare for entry. The crew experienced a one-revolution wave-off due to rain activity in the KSC vicinity.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	J.W. Moore
Associate Administrator for Space Science and Applications	B.I. Edelson
Director, Shuttle Payloads Engineering Division	M.J. Sander

The Space Shuttle Discovery lifts off from Pad A at 8:59 a.m. EST, for a five-day mission with its crew of seven to launch Telesat I, Syncom IV-3, operate the Continuous Flow Electrophoresis System and the American Flight Echocardiograph Experiment.

STS 51-B/

SPACELAB 3

Launch Vehicle—Space Transportation System (STS)—Space Shuttle Challenger.

Program Overview—See previous Shuttle missions.

Project Objectives—The first operational flight of the European Space Agency-developed space laboratory, STS 51-B was a seven-day mission to provide a high-quality microgravity environment for delicate materials processing and fluid experiments. Applications, science, and technology experiments requiring the low-gravity environment of Earth orbit and extended-duration stable vehicle attitude with emphasis on environmental observations and materials processing were to be conducted.

This mission was marked by the first deployment of free-flying payloads from Get Away Specials (GAS), and for the second time in American space flight history, Shuttle crew members performed scientific investigations continuously around the clock. This was also the second NASA mission in which scientists who developed Spacelab experiments participated actively in guiding the mission.

Spacelab was designed, developed, funded and built by the European Space Agency as Europe's contribution to the United States Space Transportation System. It represented a European investment of approximately $1 billion.

The Space Shuttle Challenger and Spacelab's basic systems were to be controlled from the Mission Control Center at NASA's Johnson Space Center (JSC), Houston, TX.

All Spacelab 3 science operations on-orbit were to be managed from the Payload Operations Control Center (POCC) located in the same building as the Mission Control Center at JSC. Members of the Marshall Space Flight Center (Huntsville, AL) mission management team, along with investigator teams which developed the Spacelab 3 experiments, were to monitor, direct, and control the experiments from the ground control center.

During the mission, NASA's Tracking and Data Relay Satellite System (TDRSS) was to handle most of the communications and data transmissions between the 51-B/Spacelab 3 and the ground. NASA's worldwide Ground Spacecraft Tracking and Data Network (GSTDN), operated by the Goddard Space Flight Center in Greenbelt, MD, was to be used when TDRSS coverage was not available. A special Spacelab Data Processing Facility at Goddard was to handle the steady flow of scientific and engineering data.

Project Payload—Spacelab 3 was a microgravity mission with 15 experiments in five major disciplines: materials science, life sciences, fluid mechanics, atmospheric science, and astronomy. (Two of these investigations were reflight instruments which had flown previously aboard Spacelab 1, launched on November 28, 1983: one in materials science, Mercury Iodide Crystal Growth [France]; and one in astronomy, Very Wide Field Camera [France]). Spacelab 3 also was to deploy two Get Away Specials containing satellites: an air traffic control radar system calibrator called NUSAT for Northern Utah University Satellite; and a Global Low Orbit Message Relay satellite (GLOMR) for data relay and communications.

Of the 15 experiments onboard Spacelab 3, 12 were developed by U.S. scientists, two by French scientists and one by Indian scientists.

Some of the experiments were to be performed in reusable "minilab" facilities inside Spacelab's long habitable module, where scientists would work in a shirtsleeve environment. Five such units being flown for the first time on this mission included two crystal growth facilities, an animal housing complex for primates and rodents, and two units for investigating fluid behavior in low gravity.

For those experiments requiring direct exposure to space, there was an experiment support structure, a lightweight carrier bridging the payload bay.

Marshall Space Flight Center was responsible for the NASA-sponsored portion of the payload and for overall management of the mission.

The seven-person crew was commanded by Robert Overmyer, a veteran NASA astronaut who served as pilot on the fifth Shuttle mission. He was assisted by pilot Frederick Gregory, on his first space mission.

Two of the scientists who developed Spacelab 3 experiments conducted onboard research as payload specialists during the mission: Dr. Lodewijk van den Berg, a materials scientist from EG&G Energy Management Corp., Goleta, CA; and Dr. Taylor Wang, a fluid physicist from NASA's Jet Propulsion Laboratory, Pasadena, CA. These two were the second pair of career scientists ever to work aboard Spacelab.

Scientific research was also performed by three NASA mission specialists: Dr. Don Lind, a high-energy astrophysicist, and Drs. Norman Thagard and William Thornton, both medical doctors making their second Shuttle flights.

An artist's concept of Spacelab, the multipurpose laboratory that enabled scientists to conduct experiments in the gravity-free environment of space.

Project Results—With Spacelab in its cargo bay and a seven-man crew aboard, Challenger was launched from Kennedy Space Center, FL at 12:02 p.m. (EDT) on April 29, 1985.

Approximately one hour and 25 minutes following the launch and insertion into a 190-mile (352-kilometer) orbit, the crew opened Challenger's payload bay doors and powered up Spacelab's electrical systems. The Spacelab 3 payload was activated approximately 6-1/4 hours after launch and was deactivated approximately 10-1/2 hours before landing.

The 51-B flight of Spacelab 3 was the first mission to deploy free-flying Get Away Specials (GAS). While the NUSAT satellite was successfully deployed on time, the GLOMR satellite failed to deploy from its GAS canister and was returned to Earth.

Spacelab 3 was the second mission to use a continuous crew operations schedule. The "Gold" team of Lind, Thornton, and Wang, plus commander Overmyer rotated on a 12-hour work-then-sleep schedule with the "Silver" team of Thagard, van den Berg, and pilot Gregory.

All 15 of the scientific investigations met the primary objectives and most of the secondary objectives, except the Very Wide Field Camera, a camera-telescope mounted in the Spacelab scientific airlock to take wide-angle pictures of the sky in ultraviolet wavelengths in order to make an ultraviolet map of the celestial sphere.

Observations using the Very Wide Field Camera (VWFC) began as scheduled on the first day of the mission. The instrument performed nominally in its first deployment, but subsequently could not be deployed when a bent latch handle on the scientific airlock precluded further airlock operations. Ground teams assessed the airlock malfunction but determined that in-flight maintenance was inappropriate. During the initial extension into space, the camera acquired its

The seven members of the Space Shuttle 51-B flight: (standing, left to right) Mission Specialist Don Lind, Payload Specialist Taylor Wang, Mission Specialists Norman Thagard and William Thornton, and Payload Specialist Lodewijk van den Berg; (seated, left to right) Commander Robert Overmyer and Pilot Frederick Gregory.

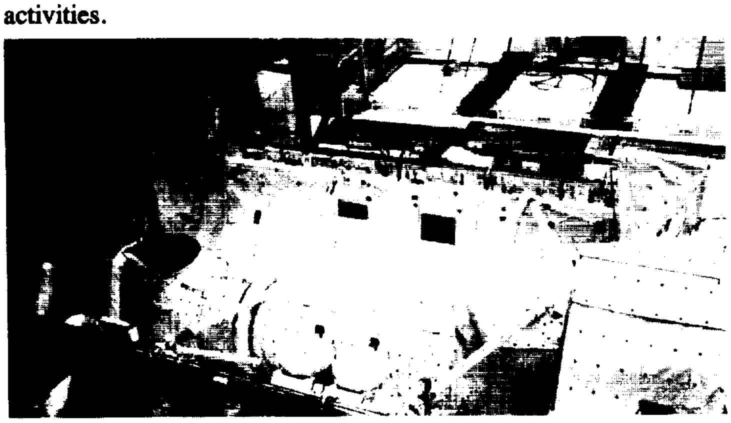
first target and a very brief one-minute exposure was made. However, the five subsequent operations, with exposure times ranging from 6 to 16 minutes, had to be suspended. Consequently, this secondary investigation did not meet its objectives, and it was not able to continue the ultraviolet survey of the sky begun on the Spacelab 1 mission.

Flight Day Two was a day of firsts, including the first systematic observations of aurora from space, using the Auroral Imaging Experiment, and resulting in the most complete set of auroral images from a manned mission. Of the 21 scheduled opportunities for auroral observations, 18 were accomplished, with auroras clearly visible on each.

The first study of fluids, using the Drops Dynamics Module (DDM) and Geophysical Fluid Flow Cell (GFFC) Facilities, also was accomplished on the second day. After initial startup difficulties, the payload specialist, Wang, was forced to perform significant in-flight maintenance on the DDM, after which the instrument operated successfully. This experiment marked the first time a principal investigator operated and repaired his own experiment in space as a Spacelab crew member. Close interaction between the ground teams and the flight crew, including the principal investigator/payload specialist, resulted in the recovery of this investigation and the accomplishment of virtually all the intended research.

Flight Day Two also marked the first observation of crystals growing in space: the Fluid Experiment System (FES) facility enabled scientists to see in detail, for the first time, the crystal growth process in a microgravity environment and to determine the differences between crystal growth on the ground and growth in microgravity where convection effects are negligible.

Though differences existed between the premission planned times for Spacelab and experiment activities and the actual times, they were most often due to experiment troubleshooting, in-flight maintenance procedures, and requests for additional experiment operations. Sufficient crew time and shuttle resources were available to accomplish these unplanned tasks in addition to all planned activities.



This photo shows the tunnel connecting Spacelab 3 with the Challenger in High Bay 1 of the Orbiter Processing Facility at Kennedy Space Center, FL.

An experiment designed to obtain fundamental information related to the chemistry and physics of the Earth's upper atmosphere using techniques of infrared absorption spectroscopy, the Atmospheric Trace Molecules Spectroscopy (ATMOS) experiment, was deactivated early due to a pressure leak in its laser subsystem. However, the experiment was rated one of the most successful in the Spacelab 3 mission, with a total harvest of data of more than 300 million measurements of the atmosphere at altitudes from 6 to 90 miles (10 to 150 kilometers).

At 12:02 p.m. (EST) on May 6, 1985, after a mission elapsed time of 168 hours and 9 minutes, Challenger landed at Edwards Air Force Base in California.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	Jesse W. Moore
Office of Space Science and Applications, Program Scientist	John Theon
Office of Space Science and Applications, Program Manager	Robert Schmitz
Associate Administrator for Space Science and Applications	Dr. Burton I. Edelson,
Acting Director, Shuttle Payloads Engineering Division	Robert H. Benson

Marshall Space Flight Center, Huntsville, AL

Spacelab 3 Mission Scientist	Dr. George H. Fichtl
Assistant Mission Scientist	Kelly Hall
Mission Manager	Joseph Cremin
Assistant Mission Manager	Robert McBrayer

Contractors:

European Space Agency—Prime Contractor	Spacelab Development

Co-Contractors:

NASA-Prime Contractor	Spacelab Support

Spacelab 3, NASA and ESA Investigation and Principal Investigators

Discipline	Title	PI Name/Organization
Material Sciences	Fluid Experiment System	Dr. Ravindra B. Lal, Alabama A&M University, Huntsville, AL
Material Sciences	Vapor Crystal Growth System	Wayne F. Schnepple, EG&G Energy Measurements, Inc., Goleta, CA
Material Sciences	Mercury Iodide Crystal Growth	Dr. Robert Cadoret, Laboratoire de Cristallographie et de Physique, Les Cexeaux, France
Fluid Mechanics	Drop Dynamics Module	Dr. Taylor G. Wang, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, CA
Fluid Mechanics	Geophysical Fluid Flow Cell Experiment	Dr. John Hart, University of Colorado, Boulder, CO
Life Sciences	Ames Research Center Life Sciences Payload: • Rodent RAHF Test • Primate RAHF Test • Dynamic Environ Monitor System • Biotelemetry System	Dr. Paul X. Callahan, and Dr. John W. Tremor, National Aeronautics and Space Administration, Ames Research Center Moffett Field, CA
Life Sciences	Autogenic Feedback Training	Dr. Pat Cowings, National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA
Life Sciences	Urine Monitoring Invest.	Dr. Howard Schneider, National Aeronautics and Space Administration, Johnson Space Center, Houston, TX

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Atmospheric Sciences and Astronomy	Atmospheric Trace Molecules Spectroscopy	Dr. C. B. Farmer, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, CA
Atmospheric Sciences and Astronomy	Studies of the Ionization of Solar and Galactic Cosmic Ray Heavy Nuclei	Dr. Sukumar Biswas, Tata Institute of Research, Bombay, India
Atmospheric Sciences and Astronomy	Very Wide Field Camera	Dr. Georges Courtes, Laboratoire d'Astronomie Spatiale, Marseilles, France
Atmospheric Sciences and Astronomy	Auroral Observations	Dr. Thomas J. Hallinan, Geophysical Institute, University of Alaska, Fairbanks, AK

STS 51-G/

SPARTAN-1
MORELOS-A
ARABSAT-1B
TELSTAR 3-D

Launch Vehicle—Space Transportation System (STS), Space Shuttle Discovery (OV-103). Rockwell International, Downey, CA.

Program Overview—See previous STS missions.

Project Objectives—To carry three communications satellites, a deployable/retrievable spacecraft called Spartan and six Getaway Special canisters, as well as several middeck experiments, into space. One of the middeck experiments was for the Strategic Defense Initiative (SDI) program, and another was a materials processing furnace.

Spacecraft Payload—Morelos-A, a Mexican communications satellite, and the first of two domestic communications satellites planned for Mexico to provide advanced telecommunications to even the most remote parts of Mexico.

Arabsat-A, owned by the Arab Satellite Communications Organization and built by Aerospatiale, was designed to provide telecommunications links between the member nations.

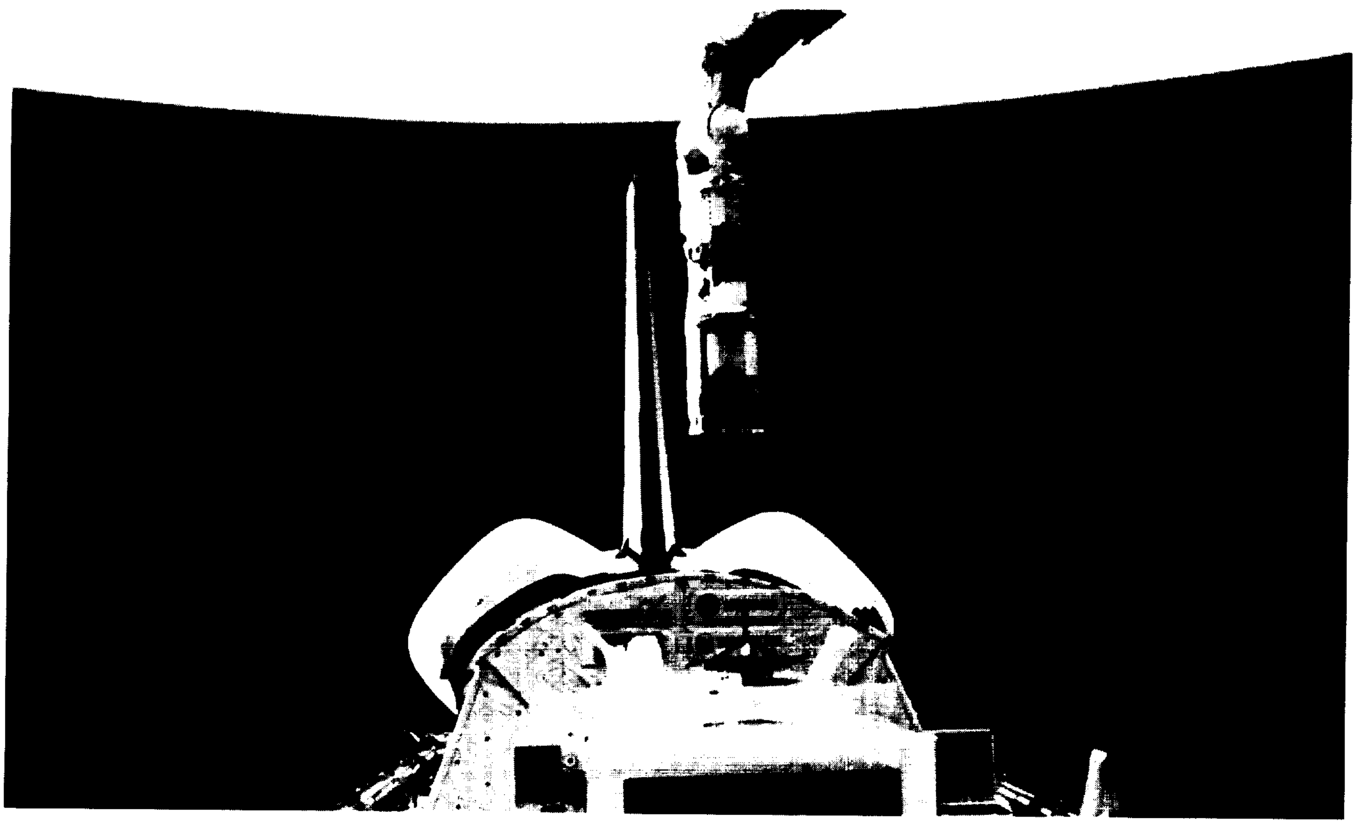
Telstar 3-D—An American domestic communications satellite owned by American Telephone and Telegraph (AT&T). It was designed to provide services to the continental United States, Alaska, Hawaii and Puerto Rico.

All three communications satellites were spring-ejected from the orbiter. All three were boosted into geosynchronous orbit by a Payload Assist Module (PAM) booster.

Other payloads included:

- Spartan—An acronym for Shuttle Pointed Autonomous Research Tool for Astronomy, Spartan was designed to be placed outside the Shuttle by the Remote Manipulator System (RMS) to search for hot gas clouds in galaxy clusters and to perform a survey of X-ray sources in our own galaxy.
- French Postural Experiment (FPE)—Designed to help scientists better understand the human body's postural adaptation in space.
- Automated Directional Solidification Furnace—Designed for materials processing experimentation.
- High-Precision Tracking Equipment was flown by the Department of Defense as part of its Strategic Defense Initiative (SDI) program.
- The Getaway Special experiments included three from West Germany designed to study materials processing and the behavior of liquid propellants, a U.S. Air Force/U.S. Naval Research Laboratory investigation of the ultraviolet radiation environment in space. A fifth canister contained a package of nine student experiments in biological and physical science, and the sixth canister contained a Goddard Space Flight Center investigation of a developmental heat transfer system.

- **Project Results**—Discovery was launched from the Kennedy Space Center at 7:33 a.m. EDT on June 17, 1985. Following a successful mission of seven days, one hour and 39 minutes, it landed at Edwards Air Force Base, CA, at 9:12 a.m. EDT (Orbit 112) on June 24, 1985. The STS 51-G crew was composed of Daniel C. Brandenstein (Capt., USN), Commander; John 0. Creighton (Cmdr., USN), Pilot; Steven R. Nagel (Lt.Col., USAF), John M. Fabian (Col., USAF), and Shannon W. Lucid (Ph.D.), Mission Specialists; and Prince Sultan Salman Al-Saud of Saudi Arabia and Patrick Baudry, a lieutenant colonel in the French Air Force, Payload Specialists.



This onboard scene from 51-G Spartan 1 site in cargo bay of Discovery prior to being set into space for a few days of free-flying in Earth orbit.

INTELSAT V-A (F-11)

Launch Vehicle—Launched by the Atlas G/Centaur D-lA, the launch vehicle had the following characteristics: total length - 137 feet (41.75 meters) 7 inches (17.78 centimeters); diameter - 10 feet (3.04 meters); thrust (Atlas Booster) 377,500 pounds (169,875 kilograms); thrust (Atlas Sustainer) - 60,000 pounds (27,000 kilograms); thrust (Centaur) - 32,800 pounds (14,760 kilograms); gross weight (total vehicle at liftoff) 356,005 pounds (160,202 kilograms) (less spacecraft); guidance - Centaur Inertial Guidance.

Various sequence and configuration changes were incorporated into the Atlas Centaur launch vehicles for INTELSAT V-A (from previous INTELSAT V launch vehicles) to improve performance for accommodating the heavier spacecraft weight and to assist spacecraft spinup.

Project Objectives—INTELSAT V-A (F-11) was the second in a series of improved INTELSAT commercial communications satellites to be launched by a NASA Atlas Centaur (AC-64) launch vehicle from the Eastern Space and Missile Center (ESMC), Cape Canaveral Air Force Station, FL.

The INTELSAT Global Satellite System is comprised of two elements: the space segment, consisting of satellites owned by INTELSAT positioned over the Atlantic, Indian, and Pacific Ocean regions; and the ground segment, consisting of Earth stations owned by telecommunications entities in the countries in which they are located. This INTELSAT satellite was assigned to the Indian Ocean region, and replaced INTELSAT V (F-1).

Spacecraft Description—The INTELSAT V-A spacecraft weighed approximately 4,402 pounds (1,980.9 kilograms) at separation from the Centaur, including the solid propellant apogee kick motor (AKM) that is used for circularization in the geosynchronous orbit.

With the antenna and solar array deployed, the spacecraft was about 51 feet (15.54 meters) wide, as measured across the solar panels and about 22 feet (6.7 meters) high. In orbital operation, the spacecraft is three-axis stabilized with the body-fixed antenna pointing constantly at the Earth and the solar array rotated to point at the Sun.

Spacecraft Payload—The INTELSAT V-A had a capacity of 13,500 voice circuits plus two television channels. Contributions had been made to the design, development, and manufacture of INTELSAT V-A by aerospace manufacturers around the world under the prime contractor, Ford Aerospace and Communications Corporation of the United States.

Project Results—The INTELSAT VA (F-11) was launched successfully on June 29, 1985 by the Atlas Centaur 64 (AC-64) from the ESMC.

The Atlas Centaur placed the spacecraft in an 80-nautical-mile (148-kilometer) perigee by 657-nautical-mile (1,216-kilometer) apogee elliptical orbit. Final altitude was 19,324 nautical miles (35,826 kilometers) over the Indian Ocean.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	Jesse W. Moore
Director, Space Transportation Support	J. B. Mahon
Atlas Centaur Manager	Jay A. Salmanson

Kennedy Space Center, FL

Director, Expendable Vehicles Operations	Charles D. Gay
Chief, Centaur Operations Division	James L. Womack
Chief, Automated Payloads Division	Donald G. Sheppard
INTELSAT Spacecraft Coordinator	Larry F. Kruse

Lewis Research Center, Cleveland, OH

Deputy Manager, Atlas Centaur Project Office	John W. Gibb
Mission Project Enginee	Richard E. Orzechowski

Contractors

Ford Aerospace and Communications Corporation Palo Alto, CA	INTELSAT V-A Spacecraft
General Dynamics/Convair San Diego, CA	Atlas Centaur Vehicle
Honeywell, Aerospace Division St. Petersburg, FL	Centaur Guidance Inertial Measurement Group
Pratt & Whitney West Palm Beach, FL	Centaur RL-10 Engines
Teledyne Systems Co. Northridge, CA	Digital Computer Unit/ PCM Telemetry

STS 51-F/ SPACELAB 2

Launch Vehicle—Space Transportation System (STS)—Space Shuttle Challenger.

Program Overview—See previous STS missions.

Project Objectives—The second operational flight of Spacelab, Flight 51-F/Spacelab 2, marked the first flight of an igloo-pallet configuration and a new Instrument Pointing System (IPS). Spacelab 2 flew shortly after Spacelab 3 because of a delay in completing the Instrument Pointing System.

The seven-day mission was the second verification test flight and the third dedicated mission for the space laboratory developed for NASA by the European Space Agency (ESA).

The pallet-only configuration of Spacelab 2 consisted of unpressurized platforms (pallets) in the payload bay which, with the pointing system, turned Spacelab into a unique orbiting observatory for studying the Sun, stars and space environment.

Because this was Spacelab's first pallet-only flight, the primary mission objectives were to verify the Spacelab systems and to determine the interface capability of Spacelab and the orbiter.

A secondary, but important objective was to obtain scientific and technology data to demonstrate Spacelab's capability to conduct investigations in a number of disciplines on a single mission. Thirteen investigations in seven scientific disciplines were chosen to exercise Spacelab's capabilities to the fullest while collecting valuable research data.

The 51-F orbiter and Spacelab's basic systems were controlled from the Payload Operations Control Center (POCC) at Johnson Space Center, Houston, TX. This was the third NASA mission in which scientists who developed Spacelab experiments, called principal investigators, participated actively in guiding the mission: helping to train and select the payload specialists and working closely with the management team to plan the mission. During the flight, these principal investigators worked in the POCC alongside the mission control teams.

Throughout the mission all Spacelab 2 science operations were managed from the POCC at Johnson. During the mission, Spacelab systems also were monitored 24 hours a day from the Huntsville Operations Support Center (HOSC) in Huntsville, AL. Both POCC and HOSC personnel worked closely with the Johnson Mission Control Center (MCC) staff, which was responsible for controlling the orbiter Challenger and basic Spacelab systems.

Most of the communications and data transmissions during the mission were handled by NASA's Tracking and Data Relay Satellite System (TDRSS), managed by Goddard Space Flight Center, Greenbelt, MD. NASA's worldwide Ground Spacecraft Tracking and Data Network, also operated by Goddard, was used when TDRSS coverage was not available. A special Spacelab Data Processing

Facility at Goddard received the steady flow of scientific and engineering data from Spacelab.

Project Payload—The mission of Spacelab 2 was to verify the ESA-built Spacelab configuration and conduct application, science, and technology investigations that required direct exposure to space above Earth's atmosphere and accurate pointing at the Sun and other celestial targets.

The overall Spacelab configuration consisted of three pallets, an igloo and a pointing system. Each U-shaped pallet was 10 feet (3.05 meters) long and 13 feet (3.96 meters) wide and was covered with aluminum honeycomb panels. The pallets mounted directly to the orbiter and experiments were attached to the pallets via different interfaces. This mission was to verify that the pallet configuration, augmented by the igloo and the pointing system, was satisfactory for observations and research.

The igloo was a cylindrical shell, with a volume of about 53 cubic feet (1.5 cubic meters) and weighing about 1,408 pounds (638.6 kilograms) fully equipped, attached to the first of the unpressurized platforms (pallets), housing many of the systems such as computers, data recorders, transmission and thermal control. These systems previously had been located inside a pressurized laboratory module element flown on the two earlier dedicated Spacelab missions, but the module was not required for this flight.

A new Spacelab component, the ESA-developed Instrument Pointing System, was tested during its inaugural flight. On the first pallet, three solar instruments and one atmospheric instrument were attached to the pointing system, which could aim them more accurately than the Shuttle alone and keep them fixed on targets as the Shuttle moved. The pointing system had a relative accuracy of two arc seconds (one eighteen hundredth of a degree), which meant it could remain stably pointed at an object the size of a quarter from a distance of one and a half miles.

Spacelab 2 was an interdisciplinary mission, with 13 investigations in seven scientific disciplines: solar physics, atmospheric physics, plasma physics, high-energy astrophysics, infrared astronomy, technology research and life sciences. Eleven of the investigations were developed by U.S. scientists and two by scientists from the United Kingdom. Also, just prior to the scheduled launch date, a 14th experiment (Protein Crystal Growth), located in the orbiter mid-deck, was added to the Spacelab 2 payload.

NASA's Marshall Space Flight Center, Huntsville, AL, was responsible for overall management of the Spacelab 2 mission. This involved overseeing all aspects of the mission including experiment selection, payload crew training, mission planning and realtime mission support.

Like the two previous Spacelab missions, 51-B and STS-9, the mission timeline for flight 51-F called for rotating shifts. Two teams, Blue and Red, worked alternating shifts of 11 to 12 hours. The Blue team consisted of Mission Specialist Anthony W. England, Payload Specialist John-David F. Barto, and

Mission Specialist F. Story Musgrave. The Blue Team was composed of Mission Specialist Karl G. Henize, Payload Specialist Loren W. Acton, and Pilot Roy D. Bridges, Jr. Commander C. Gordon Fullerton was available to work both shifts as needed.

Unlike previous missions, however, the crew did not operate instruments from inside the habitable module, which was not included on this flight, but instead worked inside the orbiter aft flight deck, located directly behind the cockpit. Equipment, such as the Spacelab computer consoles, television monitors, controls for the Instrument Pointing System, data collection and various experiments were mounted along panels in the U-shaped work area.

Project Results—The Space Shuttle Challenger with its seven-person crew and Spacelab 3 payload was launched from Kennedy Space Center, FL at approximately 5 p.m. EDT on July 29.

On July 12, the launch countdown was aborted at T-4.734 seconds when the Space Shuttle Main Engine (SSME) #2 chamber cooling valve did not respond properly to a command to close partially. The procedure to recycle the main propulsion system delayed the launch to the July 27-31 timeframe. Two other attempts at launch were discontinued. During a planned hold on July 27 a left Solid Rocket Booster (SRB) yaw rate gyro failed and a software patch was prepared to use the corresponding right SRB gyro signal. Because the software had to be dumped and reloaded, and the IMUs realigned, the launch was delayed to 5 p.m. EDT on July 29.

The flight was rated highly successful: all of the planned 13 Detailed Test Objectives (DTOs) were accomplished relative to Spacelab verification flight testing. The test objectives are grouped into eight different subsystems of disciplines: the Environmental Control Subsystem, Structures Subsystem, Command and Data Management Subsystem, Environment, Electrical Power Distribution Subsystem, Instrument Pointing Subsystem, Materials, and Contamination.

On Flight Day Two, during verification flight testing of the Instrument Pointing Susbsystem, problems of acquiring and fine tracking the Sun using the optical sensor package occurred. After these problems were resolved 16 consecutive solar acquisition passes were accomplished using the optical sensor package's fine track mode.

The Spacelab 2 mission provided an example of the evolutionary nature of scientific research. Although each experiment began the mission with clearly defined objectives and designated periods of operation, the mission plan was continuously changing. Solar observations, for example, were planned orbit-by-orbit on the basis of data gained during previous orbits and changing conditions on the Sun. Data collected by an infrared telescope constituted not a survey of the sky as planned but a complete summary of potentially useful information about background radiation which interfered with astronomical scanning. If a data-taking opportunity arose that was not in the timeline, scientists often responded through quick replanning. In this evolving, responsive fashion, the scientific results of Spacelab 2 steadily mounted.

Of the 14 experiments supported by 17 principal investigators, most scientists reported meeting at least half of their planned objectives with many reporting 100 percent success. On the basis of preliminary data analysis, most of the investigators reported first-time-ever observations or surprising results.

In the life sciences, an experiment to measure blood levels of biologically active vitamin D metabolites in the Spacelab flight crew members accomplished 100 percent of the planned objectives.

Another life sciences experiment, "Interaction of Oxygen and Gravity Influenced Lignification," designed to establish the overall effect of oxygen on the formation of lignin, a substance in woody plants, independent of any gravity effects, accomplished 100 percent of its objectives, with a real-time downlink of quality video.

In plasma physics, three experiments, the Ejectable Plasma Diagnostics Package; Plasma Depletion Experiments for Ionospheric and Radio Astronomical Studies; and Vehicle Charging and Potential, returned useful data, although both accomplished only a percentage of the planned objectives.

A Small Helium-Cooled Infrared Telescope failed to achieve its primary objective to conduct an all-sky survey of diffuse emission and extended sources in the infrared, although a section of the galaxy was mapped in shorter wavelengths.

All of the planned objectives to determine the abundance of distributions of elements and isotopes in the cosmic radiation were met by the Elemental Composition and Energy Spectra of Cosmic Ray Nuclei Experiment in high-energy physics. Another high-energy physics experiment, Hard X-Ray Imaging of Clusters of Galaxies and Other Extended X-Ray Sources, used a dual X-ray telescope to study the temperature and mass distribution of galaxies and understand properties of intergalactic gas. The experiment met approximately 90 percent of its objectives.

Despite abbreviated operations due to an unexplained shutdown and an equally unexplained start up, one of the solar physics experiments, the Solar Magnetic Velocity Field Measurement System, provided data the scientists considered to be the best and longest run of solar granulation data collected at that time.

The Solar Coronal Helium Abundance Spacelab Experiment was used to study and make images of the structure of the Sun's corona. Downlink television from the Solar Ultraviolet High Resolution Telescope and Spectrograph revealed the birth of a spicule—very small, short-lived prominences close to the solar chromosphere, which had never been witnessed before.

The Solar Ultraviolet Irradiance Monitor, classified as an atmospheric physics experiment, verified its own spectral scans of the Sun with calibration and alignment checks.

A technology experiment, Properties of Superfluid Helium in Zero Gravity, made bulk thermal dynamics measurements of temperature variations within the dewar; attempts to make bulk fluid dynamics measurements were foiled by sensors which remained frozen throughout the mission.

The STS Flight 51-F of Spacelab 2 landed at Edwards Air Force Base, CA, on August 6, 1985, at 3:45 p.m. EDT.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	Jesse W. Moore
Office of Space Science and Applications, Program Scientist	John Theon
Office of Space Science and Applications, Program Manager	Robert Schmitz
Associate Administrator for Space Science and Applications	Dr. Burton I. Edelson
Acting Director, Shuttle Payloads Engineering Division	Robert H. Benson

Marshall Space Flight Center, Huntsville, AL

Spacelab 2 Mission Manager	Roy C. Lester
Mission Scientist	Eugene W. Urban

Contractors:

European Space Agency—Prime Contractor	Spacelab Development

Co-Contractors

NASA-Prime Contractor	Spacelab Support

Spacelab 2, NASA and ESA Investigation and Principal Investigators

Discipline	Title	PI Name/Organization
Life Sciences	Vitamin D Metabolites and Bone Demineralization	H.K. Schnoes, University of Wisconsin
Life Sciences	Interaction of Oxygen and Gravity Influenced Lignification	J.R. Cowles, University of Houston
Plasma Physics	Ejectable Plasma Diagnostics Package	L.A. Frank, University of Iowa
Plasma Physics	Plasma Depletion Experiments for Ionospheric and Radio Astronomical Studies	M. Mendillo, Boston University and A.V. DaRosa, Stanford University
Plasma Physics	Vehicle Charging and Potential	P.M. Banks, Stanford University
Infrared Astronomy	Small Helium-Cooled Infrared Telescope	G.G. Fazio, Smithsonian Astrophysical Observatory
High-Energy Physics	Elemental Composition and Energy Spectra of Cosmic Ray Nuclei	P. Meyer and D. Muller, University of Chicago
High-Energy Physics	Hard X-Ray Imaging of Clusters of Galaxies and Other Extended X-Ray Sources	A.P. Willmore, University of Birmingham, United Kingdom
Solar Physics	Solar Magnetic and Velocity Field Measurement System	A.M. Title, Lockheed Palo Alto Research
Solar Physics	Solar Coronal Helium Abundance Spacelab Experiment	A.H. Gabriel, Rutherford and Appleton Laboratory, United Kingdom, and J.L. Culhane, University College, United Kingdom

Solar Physics	Solar Ultraviolet High Resolution Telescope and Spectrograph	G.E. Brueckner, Naval Research Laboratory
Atmospheric Physics	Solar Ultraviolet Irradiance Monitor	G.E. Brueckner, Naval Research Laboratory
Technology	Properties of Superfluid Helium in Zero-Gravity	P.V. Mason, Jet Propulsion Laboratory
Technology	Protein Crystal Growth	C.E. Bugg, University of Alabama in Birmingham

STS 51-I/

ASC-1/PAM-D
AUSSAT-1/PAM-D
SYNCOM IV-4/UNQ
PVTOS (Physical Vapor Transport of Organic Solids)
SYNCOM IV-3 REPAIR

Launch Vehicle—Space Transportation System (STS) - Space Shuttle Discovery.

Program Overview—See previous Shuttle missions.

Project Objectives—The mission of the Space Shuttle Discovery on its sixth flight was to repair and salvage the lifeless Syncom IV-3 satellite on orbit and redeploy it for normal operation, and to deploy three other communications satellites: ASC-1/PAM-D for the American Satellite Company, the AUSSAT-1/PAM-D satellite for the Australian government, and the Leasat/Syncom IV-3 satellite for the U.S. Navy. The Physical Vapor Transport of Organic Solids (PVTOS) experiment, sponsored by the 3M Corporation was to be conducted in Discovery's middeck.

The on-orbit salvage of Syncom IV-3 would mark the second repair of a satellite in space.

Project Payload—In addition to equipment for the Syncom IV-3 repair, Discovery carried three communications satellites and one middeck payload on its 51-I mission.

The crew of 51-I consisted of Mission Commander Colonel Joe H. Engle; Pilot Lieutenant Colonel Richard 0. Covey; Mission Specialist James D.A. van Hoften, Ph.D.; Mission Specialist John M. Lounge; and Mission Specialist William F. Fisher, M.D.

ASC-1/PAM-D. This communications satellite was built by RCA Astro-Electronics for the American Satellite Company. The American Satellite Co. provides voice, data, facsimile and videoconferencing communications services to U.S. businesses and government agencies. ASC-1 was the first wholly-owned commercial communications satellite in a system consisting of two operational spacecraft and one ground spare.

The cube-shaped ASC-1 measures 4.3 by 5.3 by 10.5 feet (1.31 × 1.62 × 3.2 meters). With its solar panels deployed on orbit, the length increases to 46.5 feet (14.17 meters), tip to tip. Weight of the satellite as it arrived on station was 1,482 pounds (672 kilograms). ASC-1 was scheduled to be deployed on Flight Day One and boosted into its synchronous transfer orbit by the Payload Assist Module (PAM-D).

AUSSAT-1/PAM-D. This communications satellite was built by the Hughes Aircraft Company for the AUSSAT Proprietary Ltd., Australia's national satellite company. On Flight Day Two, the AUSSAT-1 satellite was deployed by the astronauts, then boosted into orbit when ground controllers in Australia fired the apogee kick motors. From that point on, AUSSAT mission events would be conducted from Australia.

Following deployment, Australian controllers conducted about three weeks of in-orbit testing on their first communications satellite.

The AUSSAT-1 satellite had 11 12-watt transponders and four 30-watt transponders to provide domestic communications to Australia's population of 15 million people and to improve air traffic control services.

SYNCOM IV-3/LEASAT. On Flight Day Three, Leasat 4 (Syncom IV-3) was ejected, using a "Frisbee"style deployment, and 51-I Pilot Covey began a series of phase and height adjust maneuvers for the Leasat 3 rendezvous, the highlight of the mission. Once Leasat was 500 feet (152.4 meters) from the Shuttle, the omnidirectional antenna automatically was raised from its stowed position, and a series of firings were initiated to place the spacecraft into geostationary orbit.

Leasat has a life expectancy of 10 years.

PVTOS (Physical Vapor Transport of Organic Solids)—middeck payload
The second in a series of experiments planned by 3M Corp., the PVTOS experiment involved the vaporizing of solid materials into a gaseous state to form thick crystalline films on selected substrates of sublimable organics. Crystals produced by PVTOS were studied for their optical properties and other characteristics that might ultimately have important applications to 3M's business in the areas of electronics, imaging and health care.

The Extravehicular Activity (EVA) required to repair the ailing Leasat 3 (Syncom IV-3) satellite was scheduled for Flight Day Seven, after depressurization of Discovery's crew cabin beginning on Flight Day Six, and checkout of the repair equipment.

Leasat 3 was successfully deployed April 13, 1985 during the 51-D mission but the spacecraft's automated sequencer failed to initiate antenna deployment, spinup and ignition of the perigee kick motor. That mission was extended two days and an unplanned spacewalk was performed in an unsuccessful attempt to activate the satellite. At the time of 51-I, the satellite was drifting in low-Earth orbit without command and telemetry capability.

Discovery approached within 35 feet of the slow-spinning satellite. Once secured to the Shuttle's robot arm, Mission Specialist van Hoften plucked the ailing Leasat out of space with a special device and presented it to Mission Specialist Fisher. Fisher was secured at a work station in Discovery's payload bay.

Fisher performed the mechanical repair work to various parts of the spacecraft including installation of the ground control electronics box, the unit to deploy the omni antenna, and verify that Leasat's power was on.

After the salvage was completed, van Hoften began the deploy by lifting the seemingly weightless spacecraft with a spin up bar to start it rotating at about 8-10 rotations per minute. After Leasat was redeployed it was turned over to Hughes for normal operation.

Flight Day Eight was reserved for the crew to stow cabin equipment and perform normal flight control system work.

Project Results—The Space Shuttle Discovery was launched on flight 51-I at 6:58 a.m. (EDT) on August 27 from Kennedy Space Center, FL, with three communications satellites aboard.

The launch was initially delayed from August 24 to August 25 due to thunderstorms and lightning within the launch area. The launch was further delayed until August 27 to replace a failed GPC 5 computer and to inspect the main engine ducts.

A sunshield on the AUSSAT spacecraft became hung up on the satellite's omni antenna cross-beam when an attempt was made to reopen the sunshield to perform the AUSSAT health check, forcing the astronauts to use the RMS (Remote Manipulator System) robot arm to open the deformed sunshield. To avoid violating thermal constraints on the AUSSAT and its Payload Assist Module, the AUSSAT was deployed a day early. This caused the ASC deploy to be delayed one orbit to the eighth orbit.

The mission duration was changed from eight to seven days, and the orbiter Challenger landed at Edwards Air Force Base on September 3 at 9:16 a.m. (EDT).

INTELSAT V-A (F-12)

Launch Vehicle—Launched by the Atlas G/Centaur D-lA, the launch vehicle had the following characteristics: total length - 137 feet (41.75 meters) 7 inches (17.78 centimeters); diameter - 10 feet (3.04 meters); thrust (Atlas Booster) 377,500 pounds (169,875 kilograms); thrust (Atlas Sustainer) - 60,000 pounds (27,000 kilograms); thrust (Centaur) - 32,800 pounds (14,760 kilograms); gross weight (total vehicle at lift off) 356,005 pounds (160,202.25 kilograms) (less spacecraft); guidance - Centaur Inertial Guidance.

Various sequence and configuration changes were incorporated into the Atlas Centaur launch vehicles for INTELSAT V-A (from previous INTELSAT V launch vehicles) to improve performance for accommodating the heavier spacecraft weight and to assist spacecraft spinup.

Project Objectives—INTELSAT V-A (F-12) was the last INTELSAT commercial communications satellite to be launched by a NASA Atlas Centaur (AC-65) launch vehicle from the Eastern Space and Missile Center (ESMC), Cape Canaveral Air Force Station, FL.

The INTELSAT Global Satellite System is comprised of two elements: the space segment, consisting of satellites owned by INTELSAT positioned over the Atlantic, Indian, and Pacific Ocean regions; and the ground segment, consisting of Earth stations owned by telecommunications entities in the countries in which they are located. This INTELSAT satellite was assigned to the Indian Ocean Region and replaced INTELSAT V (F-1).

Spacecraft Description—The INTELSAT V-A spacecraft weighed approximately 4,402 pounds (1,980 kilograms) at separation from the Centaur, including the solid propellant apogee kick motor (AKM) that was used for circularization of the geosynchronous orbit.

With the antenna and solar array deployed, the spacecraft is about 51 feet (15.54 meters) wide, as measured across the solar panels and about 22 feet (6.70 meters) high. In orbital operation, the spacecraft is three-axis stabilized with the body-fixed antenna pointing constantly at the Earth and the solar array rotated to point at the Sun.

Spacecraft Payload—The INTELSAT V-A has a capacity of 13,500 voice circuits plus two television channels. Contributions have been made to the design, development, and manufacture of INTELSAT V-A by aerospace manufacturers around the world under the prime contractor, Ford Aerospace and Communications Corporation of the United States.

Project Results—The INTELSAT V-A (F-12) was launched successfully on September 28, 1985 from Eastern Space and Missile Center, Cape Canaveral Air Force Station, FL.

The Atlas Centaur placed the spacecraft in an 80-nautical-mile (148-kilometer) perigee by 657-nautical-mile (1,216-kilometer) apogee elliptical orbit. Final altitude was 19,324 nautical miles (35,826 kilometers) over the Indian Ocean.

Major Participants—

NASA Headquarters, Washington, DC

Associate Administrator for Space Flight	Jesse W. Moore
Director, Space Transportation Support	J.B. Mahon
Atlas Centaur Manager	Jay A. Salmanson

Kennedy Space Center, FL

Director, Expendable Vehicles Operations	Charles D. Gay
Chief, Centaur Operations Division	James L. Womack
Chief, Automated Payloads Division	Donald G. Sheppard
INTELSAT Spacecarft Coordinator	Larry F. Kruse

Lewis Research Center, Cleveland, OH

Deputy Manager, Atlas Centaur Project Office	John W. Gibb
Mission Project Engineer	Richard E. Orzechowski

Contractors

Ford Aerospace and Communications Corporation Palo Alto, CA	INTELSAT V-A Spacecraft
General Dynamics/Convair San Diego, CA	Atlas Centaur Vehicle
Honeywell, Aerospace Division St. Petersburg, FL	Centaur Guidance Inertial Measurement Group
Pratt & Whitney West Palm Beach, FL	Centaur RL-10 Engines
Teledyne Systems Co. Northridge, CA	Digital Computer Unit/ PCM Telemetry

STS 61-A

SPACELAB D-1

Launch Vehicle—Space Transportation System (STS)—Space Shuttle Challenger.

Program Overview—See previous Shuttle missions.

Project Objectives—Weightlessness was the common denominator of the approximately 75 experiments carried out onboard the German Spacelab mission D-1. The 61-A flight marked the first time a Spacelab payload came from Europe completely checked out and ready for installation in the orbital laboratory.

Managed by the Federal German Aerospace Research Establishment (DVFLR) for the German Federal Ministry of Research and Technology (BMFT), the Spacelab D-1 was the first of a series of dedicated West German missions on the Space Shuttle.

Mission 61-A was also to deploy the Global Low Orbiting Message Relay Satellite (GLOMR), a data-relay, communications spacecraft carried aboard the Shuttle in a Get Away Special (GAS) canister. An attempt was made to deploy the GLOMR satellite on Mission 51-B in April 1985, but problems with the battery supply prevented a successful deployment.

Like previous Spacelab astronauts, astronauts aboard Challenger for the 61-A flight of Spacelab D-1 worked round the clock in two shifts.

And, as with previous Space Shuttle missions, NASA would maintain control over the Shuttle vehicle for overall safety and conduct of the flight. For D-1, the Federal Republic of Germany provided management responsibility for the scientific mission to be carried out during the seven-day flight. The payload operations control center was located at the German Space Operations Center (GSOC) located in Oberpfaffenhofen, near Munich.

Payload Description—Mission 61-A carried a series of experiments, primarily in microgravity, arranged according to scientific discipline into seven payload elements, and housed together with their necessary technical infrastructure within standard 19-inch Spacelab racks in the Spacelab module.

In addition, Spacelab D-1 carried the Global Low Orbiting Message Relay Satellite (GLOMR), a data-relay, communications spacecraft. Mounted on the port side of the orbiter payload bay in the vicinity of the Spacelab tunnel, the Getaway Special (GAS) canister with the GLOMR inside would be ejected via a standard Autonomous Payload Controller located in the orbiter aft flight deck.

The seven payload elements included basic and applied microgravity research in the fields of materials sciences, life sciences and technology, and communication and navigation, provided by German and foreign universities, research institutions and industrial enterprises as well as the European Space Agency (ESA) and NASA. The support facilities for these experiments were comprised of melting furnaces, facilities for the observation of fluid physics phenomena, chambers to provide specific environmental conditions for living test objects, and the Vestibular Sled, which would expose astronauts to defined accelerations to study the function of the inner ear.

Materials Science Double Rack (MDSR). This rack contained experimental equipment for carrying out investigations in the field of fluid physics, the solidification of metallic melts, and the growth of single crystals. This payload element already had been flown successfully on the first Spacelab mission in November 1983. Also known as "werkstofflabor" in German, this multi-use facility housed the following hardware: a mirror heating facility, a cryostat, a gradient heating facility, a fluid physics module, an isothermal heating facility and a high-temperature thermostat.

Process Chamber or "Prozesskamer" (PK). This fluid physics experiment consisted mainly of optical diagnosis equipment tailored to the requirements of the scientists. It was designed to show and measure flows, heat and mass transport, and temperature distribution during melting and solidification processes, as well as during phase changes of liquids.

The Material Science Experiment Double Rack for Experiment Modules and Apparatus (MEDEA). This experiment was composed of three largely autonomous experiment facilities. A gradient furnace conducted experiments in the metallurgical and directional solidification of different materials. Crystal growth was carried out in the monoellipsoidal mirror heating facility. A high-precision thermostat in the unit measured specific heat at the critical point of a specimen.

Compared to the MDSR, MEDEA and PK represented payload elements of a second generation with respect to technical concept and experiment installations.

Biowissenschaften (BW). This life sciences payload experiment package contained an experiment in which a small botanical garden was tended during the mission, a "frog statolith" experiment to investigate frog larvae development, and an experiment which continued the first Spacelab's medical experiments of the central venous pressure. The last experiment was designed to study fluid shifts under the effect of microgravity, as well as the adaptive behavior of the related human organs.

Biorack (BR). The Biorack was a multipurpose ESA research facility that could repeatedly perform biological experiments in weightlessness. Two incubators with different operating temperatures, a freezer and a hermetically sealed glove box were located in a single rack. To provide for the necessary controlled environment, different types of sample containers were provided, some equipped with measurement points that were controlled by the Spacelab computer system. During the ascent and descent phases, the containers with biological material were stowed and passively temperature-controlled in the middeck area to ensure late access to and early retrieval from the orbiter.

Two fully automated experiments were accommodated in supporting structures behind the Spacelab module, in the Shuttle loading area:

NAVEX. This navigation experiments payload had two main objectives: development and testing of a precise clock synchronization; and testing of a method for precise one-way distance measurement and position determination. To accomplish this, the experiment contained three cylindrical containers with two cesium atomic clocks and the necessary sender-and-receiver electronics.

Materials Science Experiment Assembly (MEA). Five NASA experiments made up of various furnaces and an acoustic positioning apparatus made up the self-contained MEA facility for multidisciplinary experiments in the materials processing field. Developed for NASA's OSTA-2, the MEA had flown on several missions.

The eight-member crew of 61-A was the largest ever flown in space. Three European payload specialists flew with a five-person NASA crew. Commander Henry (Hank) Hartsfield, was a veteran pilot of both the STS-4 and STS-41-D flights, and Pilot Steven Nagel had previously served as mission specialist aboard STS 51-G. The other NASA crew members included mission specialists James Buchli, Guion Bluford and Bonnie Dunbar. The German payload specialists were Drs. Reinhard Furrer (DFVLR - German), Ernst Messerschmid (DFVLR German) and Wubbo Ockels (ESA - Dutch).

Flight 61-A was the first mission for the three European specialists and the American Bonnie Dunbar; Buchli had flown previously on Shuttle flight 51-C, the first mission totally dedicated to the Department of Defense, and Bluford flew aboard STS-8.

Project Results—The Space Shuttle Challenger was launched from Kennedy Space Center, FL at 12:00 noon (EST) on October 30, 1985 carrying an eight-person crew, plus the Spacelab D-1 payload and the GLOMR satellite.

The mission was rated a success, with all NASA operations and support performing successfully, and a successful deploy of the GLOMR satellite.

Challenger landed at Edwards Air Force Base at 12:45 p.m. (EST) on November 6, 1985, after a seven-day, 45-minute flight.

Spacelab D-1, NASA, ESA and DFVLR Scientists and Principal Investigators

Title	PI Name/Organization
	Fluid-physics experiments
Floating-Zone Hydrodynamics	I. DaRiva, Univ. Madrid, Spain
Capillary Experiments	J.F. Padday, Kodak Ltd., Harrow, United Kingdom

Forced Liquid Motions	J.P.B. Vreeburg, NLR, Amsterdam, Netherlands
Surface-Tension Studies	D. Neuhaus, DFVLR, Cologne, Germany
Marangoni Convection	D. Schwabe, Univ. Geissen, Germany
Marangoni Flows	L. Napolitano, Univ. Naples, Italy
Marangoni Convection	A.A.H. Drinkenburg, Univ. Groningen, Netherlands
Convection in Nonisothermal Binary Mixtures	J.C. Legros, Univ. Brussels, Belgium
Bubble Transport	A. Bewersdorff, DFVLR, Cologne, Germany
Self- and Inter-Diffusion	H. Wever/G. Frohberg, TU Berlin, Germany
Thermal Diffusion	J. Dupuy, Univ. Lyon, France
Inter-Diffusion	J. Richter, WRWTH, Aachen, Germany
Homogeneity of Glasses	C. Frischat, TU Clausthal, Germany
Diffusion of Liquid Zinc and Lead	R.B. Pond, Marvalaud Inc., USA
Thermomigration of Cobalt in Tin	J.P. Praizey, CEN, Grenoble, France
Heat Capacity Near Critical Point	J. Straub, TU, Munich, Germany
Phase Separation Near Critical Point	J. Klein, Cologne, Germany
Solidification Experiments	
GETS	A. Ecker/P.R. Sahm, RWTH, Aachen, Germany
Aluminum/Cooper Phase Boundary Diffusion	J.H. Tensi, TU, Munich, Germany
Solidification Dynamics	S. Rex/P.R. Sahm, RWTH, Aachen, Germany

Dendritic Solidification of of Aluminum-Cooper Alloys	J.J. Favier/D. Camel, CEN, Grenoble, France
Cellular Morphology in Lead Thallium Alloys	B. Billia/J. Favier, Univ. Marseille France
Indium Antimonide-Nickel Antimonide Eutectics	G. Muller, Univ. Erlangen-Nuremberg Germany
Containerless Melting of Glass	D.E. Day, Univ. Missouri—Rolla, USA
Solidification of Suspensions	J. Potschke, Krupp, Essen, Germany
Particle Behavior at Solidification Fronts	D. Langbein, Batelle-Inst., Frankfurt, Germany
Skin Technology	H. Sprenger, MAN, Munich, Germany
Liquid Skin Casting of Cast Iron	H. Sprenger/I.H. Nieswaag, T.H. Delft, Netherlands
Solidification of Eutectic Alloys	Y. Malmejac, CEN, Grenoble, France
Solidification of Composite Matter	A. Deruyttere, Univ. Leuven, Belgium
Silicon-Crystal Growth by Floating Zone Technique	R. Nitsche, Univ. Freiburg, Germany
Melting of Silicon Sphere	H. Kolker, Wacker-Chemi, Munich, Germany
Doped Indium Antimonide and Gallium Indium Antimonide	C. Potard, CEN, Grenoble, France
Travelling Heater Method (GaSb)	K. W. Benz, Univ. Stuttgart, Germany
Travelling Heater Method (CdTe)	R. Nitsche, Univ. Freiburg, Germany
Travelling Heater Method (InP)	K. W. Benz, Univ. Stuttgart, Germany
Travelling Heater Method (PbSnTe)	M. Harr, Battelle-Institute, Frankfurt, Germany
Vapour Growth of Cadmium	R. Nitsche, Univ. Freiburg, Germany
Ge/GeI_4 Chemical Growth	J.C. Launay, Univ. Bordeax, France
Ge-I_2 Vapour Phase	J.C. Launay, Univ. Bordeax, France

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Vapor Growth of Alloy-Type Crystal	H. Wiedemeier, Rens. Poly, Troy, NY, USA
Semiconductor Materials	R.K. Crouch, NASA/Langley Research Center, USA
Protein Crystals	W. Littke, Univ. Freiburg, Germany
Separation of Immiscible Alloys	H. Ahlborn, Univ. Hamburg, Germany
Separation of Immiscible Liquids	D. Langbein, Battelle-Inst., Frankfurt, Germany
Separation of Fluid Bases	R. Naehle, DFVLR, Cologne, Germany
Liquid Phase Miscibility Gap Materials	H.S. Gelles, Columbus, Ohio, USA
Ostwald Ripening	H.Fischmeister, MPI, Stuttgart, Germany

Biological Experiments

Human Lymphocyte Activation	A. Cogoli, ETH, Zurich, Switzerland
Cell Proliferation	H. Planel, Univ. Toulouse, France
Mammalian Cell Polarization	M. Bouteille, Univ. Paris, France
Circadian Rhythm	D. Mergenhagen, Univ. Hamburg, Germany
Antibacterial Activity	R. Tixador, Univ. Toulouse, France
Growth and Differentiation of Bacil. Subt.	H.D. Mennigmann, Univ. Frankfurt, Germany
Effect of ug on Interaction Between Cells	O. Ciferri, Univ. Pavia, Italy
Cell Cycle and Protoplasmic Streaming	V. Sobick, DFVLR, Cologne, Germany
Dosimetric Mapping Inside Biorack	H. Bucker, DFVLR, Cologne, Germany
Frog Statoliths	J. Neubert, DFVLR, Cologne, Germany

Dorso-ventral Axis	G. Ubbels, Univ. Utrecht, Netherlands
Distribution of Cytoplasmic Determ.	R. Marco, Univ. Madrid, Spain
Embryogenesis and Organogenesis	H. Bucker, DFVLR, Cologne, Germany
Gravi-Perception	D. Volkmann, Univ. Bonn, Germany
Geotropism	J. Gross, Univ. Tubingen, Germany
Differentiation of Plant Cells	R.R. Theimer, Univ. Munich, Germany
Statocyte Polarity and Geotropic Response	G. Perbal, Univ. Paris, France

Medical Experiments

Vestibular Research	R.V. Baumgarten, Univ. Mainz, Germany
Vestibular Research	L. Young, MIT, Cambridge, Mass., USA
Central Venous Pressure	K. Kirsch, Free Univ., Berlin, Germany
Tonometer	J. Draeger, Univ. Hamburg, Germany
Body Impedance Measurement	F. Baisch, DFVLR, Cologne, Germany

Space-Time Interaction Experiments

Clock Synchronization	S. Starker, DFVLR, Oberpfaffenhofen, Germany
One-Way Determination of Distance	D. Rother, SEL, Stuttgart, Germany
Psychological Behavior in Microgravity Mass Discrimination	H.E. Ross, Univ. Stirling, UK
Spatial Description in Space	A.D. Friederici/J.M. Levelt, MPI/Univ. Nijmegen
Gesture and Speech in Microgravity	A.D. Friederici, MPI/Univ., Nijmegen
Determination of Reaction Time	H. Hoschedk/J. Hund

STS 61-B/
EASE/ACCESS MORELOS-B AUSSAT-2 RCA SATCOM K-2

Launch Vehicle—Space Transportation System (STS)—Space Shuttle Atlantis.

Program Overview—See previous Shuttle missions.

Project Objectives—The 7-day mission of flight 61-B of the Space Shuttle Atlantis had four primary objectives: it carried three communications satellites to deploy for Mexico, Australia, and RCA; also aboard was a combination of two experiments designed to study an extravehicular method of construction in space.

The release of Morelos-B, the second of a series of communications satellites for Mexico, took place on Flight Day One. This satellite was designed and built for Mexico by Hughes Aircraft Corp. to provide telephone, television and wire services to Mexico through a total of 22 transponders. Attached to the spacecraft was a Payload Assist Module (PAM-D) to boost Morelos-B into geosynchronous orbit.

The first Morelos spacecraft was deployed from the orbiter Discovery in June 1985. Morelos-B would be stationed at 113.5 degrees West Longitude, over the Equator south of Phoenix, AZ. On Flight Day Two, the crew of Atlantis deployed the Aussat II, the second of three operations satellites for the government-owned Australian National Satellite System. The first Aussat was successfully deployed from Discovery in August 1985

Also built by Hughes, Aussat II has 11 12-watt and four 30-watt transponders to provide domestic communications to Australia's population of 15 million people. The system was designed to improve both maritime and air traffic control communications, relay digital data for business purposes, provide standard telephone communications and direct satellite-to-home television broadcasts to major cities as well as to the bush country. Like Morelos-B, Aussat II had a PAM-D upper stage to boost it to geosynchronous orbit.

The third communications satellite was to be deployed on Flight Day Three. The RCA Satcom K-2 would be the first deployment of a spacecraft to use the updated D-2 model of the Payload Assist Module (PAM D-2).

The EASE/ACCESS combination payload was included to study Extravehicular Activity (EVA) dynamics and human factors in construction of structures in space.

The Experimental Assembly of Structures with Extravehicular Activity (EASE) experiment required the crew members to manually assemble an inverted tetrahedron with 12-foot sections, manipulate the entire assembled structure free of the Mission Peculiar Equipment Support Structure (MPESS), connect two beams to simulate a space station heat beam, and manipulate the beam using the foot restraint and RMS.

The Assembly Concept for Construction of Erectable Space Structure (ACCESS) experiment involved building a 45-foot (13-meter) truss manually. The EVA crew members were to erect five bays, attach a simulated utility cable and stow it, remove and replace nodes and struts, manipulate the entire structure free of the MPESS, and then reinstall the structure. The procedures would be similar to those required to construct a space station.

The 61-B mission was the first mission to include a Mexican payload specialist in the crew, the first flight of the PAM D-2 upper stage, the heaviest PAM payload (RCA SATCOM K-2), and the first assembly of a structure in space.

Payload Description—In addition to these primary payloads, the 61-B flight of Atlantis carried a Get Away Special (GAS) canister, the IMAX Payload Bay Camera (IPBC), three experiments—one in biology and two in crystal growth—and five experiments to be conducted by the Morelos payload specialist.

The seven-member crew included Commander Brewster H. Shaw, Jr., and Pilot Bryan D. O'Connor, plus Mission Specialists Mary L. Cleave, Sherwood C. Spring, and Jerry L. Ross. Two payload specialists completed the crew: Mexico's Rudolfo Neri Vela and Charles Walker of McDonnell Douglas Astronautics Co.

Deployment of the Morelos-B and AUSSAT II satellites was to be accomplished primarily under the direction of Mission Specialist Spring. Mission Specialist Ross would direct the deployment of the 4,144-pound (1,879-kilogram) RCA SATCOM K-2.

The seven members of the Space Shuttle 61-B flight: (back row, left to right) Payload Specialist Charles D. Walker, Mission Specialists Jerry L. Ross, Mary L. Cleave, Woody Spring, and Payload Specialist Rudolfo Neri Vela; (front row, left to right) Pilot Bryan D. O'Connor and Commander Brewster H. Shaw, Jr.

The attached payload GAS canister contained an experiment for Telesat Canada in which six vapor deposition tubes would create metallic deposits for generation of crystal growth to make a mirror. The experiment was selected from among nearly 300 submitted by Canadian students in a contest sponsored by Telesat Canada to stimulate Canadian student interest in the space program.

The experiment chosen, entitled "Towards a Better Mirror," proposed to fabricate mirrors in space that would provide higher performance than similar mirrors made here on Earth. Products of the experiment were to be tested post-flight using sophisticated optical techniques to determine precise measurements of the on-orbit coating process used to create the mirror.

The IMAX Payload Bay Camera (IPBC) was included to take 70mm motion pictures of the EASE/ACCESS EVA during the mission. Mounted in a pressure-sealed container with a viewing window, the camera uses a fish-eye lens and a special film format devised to project very large images on IMAX theater screens.

Also aboard was the hand-held Linhof large format camera for photography of Africa, particularly the areas of Ethiopia and Somalia, to look for surface indications that might reveal the presence of water above or below the Earth's surface.

One crystal growth experiment and the McDonnell Douglas biological experiment would be conducted by Payload Specialist Walker, of McDonnell Douglas. This was his third flight as payload specialist.

The Protein Crystal Growth Experiment (PCGE) was a hand-held device containing 48 small crystal growth chambers lined with a solution such as alcohol or saline to precipitate crystal growth. A small drop of protein solution would be injected into each chamber shortly after entering orbit, and up to six of the growth chambers were then "seeded" by injecting a microscopic particle of crystallized protein to form a nucleus for a larger crystal. The possibility of crystallizing biological materials such as hormones, enzymes and other proteins has medical implications for the synthesis of pharmaceuticals to enhance or inhibit functions of biological proteins.

Flight 61-B was the seventh trip into space for the McDonnell Douglas Continuous Flow Electrophoresis Experiment (CFES). The objective of this mission was to separate a sufficient quantity of biological material for animal and clinical testing of a breakthrough pharmaceutical.

The other crystal growth experiment was the Diffusive Mixing of Organic Solutions (DMOS) by the 3M Corp. This experiment was intended to grow organic crystals in near-zero gravity in an effort to produce single crystals that were purer and larger than those available on Earth to study their optical and electrical properties.

One potential application of this experiment is the manufacture of optical devices comparable to electronic devices, though much faster. Possible uses include optical switches and computers that process information with light instead of electricity.

The DMOS-2 experiment was contained within six football-sized chemical reactors carried in the middeck area, housed in an Experimental Apparatus Container supplied by NASA.

Payload Specialist Rudolfo Neri Vela also was to conduct four experiments while in orbit: transportation of nutrients inside bean plants, inoculation of group bacteria viruses, germination of three seed types including abergon, lentil and wheat, and medical experiments which included measurements testing of internal equilibrium and volume change of the leg due to fluid shifts in zero-gravity. In addition, Vela would photograph Mexico for Earth resources purposes.

Also, both Vela and Payload Specialist Walker would test for the rate of absorption of two medications into the bloodstream while in space: Tylenol and Scopedex.

The Orbiter Experiment (OEX), an onboard experimental digital autopilot software package, was retested on this flight. To be used with the orbiter, another space vehicle, or even space station, the OEX was designed to provide precise stationkeeping capabilities between various vehicles operating in space.

Project Results—The orbiter Atlantis, with its multitude of payloads and experiments plus a seven-man crew, was launched from the Kennedy Space Center, FL at 7:29 p.m. (EST) on November 26, 1985. After landing almost seven days later (6 days, 21 hours, 5 minutes) at Edwards Air Force Base, California, at 4:34 p.m. (EST) on December 3, the mission was rated a success.

Landing was on orbit 109 instead of 110 to allow for a better Sun angle for the approach to the runway.